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THE

ECONOMY OF NATURE

EXPLAINED AND ILLUSTRATED

ON THE

PRINCIPLES

OF

MODERN PHILOSOPHY.

BY

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IN THREE VOLUMES.

WITH FORTY-SIX PLATES.

VOL. II.

LONDON:
PRINTED FOR J. JOHNSON, N° 72, ST. PAUL'S CHURCH YARD,
1796.

BROMLEY
3819

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BOOK VI.

OF MINERAL SUBSTANCES, AND THE STRUCTURE OF THE EARTH.

CHAPTER I.

* OF SALTS IN GENERAL.

Definition of Salts.—Salts ſimple and compound.—What are called ſimple Salts are in reality compound Bodies.—Oxygenous Principle.

THOSE ſubſtances are denominated ſalts which are fuſible, volatile, ſoluble † in water, not inflammable, and ſapid when applied to the tongue. The moſt ſimple ſtate of ſalts, is a maſs, white, brittle, and in ſome degree tranſparent. Salts in certain degrees of heat are fluid and tranſparent, like oil. They differ in their degree of fuſibility and volatility. Some aſſume the form of vapour in the ordinary temperature of the atmoſphere, others in a great degree of heat remain fixed. Previous to treating of the particular ſubſtances of this claſs, it will be proper to make a few obſervations on the formation of ſalts in general. Salts are either ſimple or compound. Simple ſalts are diſtinguiſhed into alkalis and acids; and from the union of an acid and an alkali are produced compound ſalts, which are alſo called neutral, becauſe by this combination the characteriſtic properties both of the acid and alkali are loſt, and a new body is formed, which is extremely inert, in compariſon with the two ſubſtances of which it is compoſed. Several of the earths and ſome of the metals are alſo capable of being united with acids, and the compound forms a ſalt more or leſs perfect.

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* This part of the work will neceſſarily be in ſome meaſure chemical; but it is only by chemical proceſs that we can reach the conſtituent particles of natural bodies. The reaſon of this arrangement will be obvious. The object of this book is to treat of the ſtructure of the earth; but it is neceſſary to be firſt informed concerning the different matters of which it is compoſed.

† The diſtinction between ſolution and mixture has been already ſtated; but it may not be improper to remind the reader, that in ſolution the body which was ſolid is ſo completely in union with the fluid or menſtruum, that the compound is completely tranſparent, though not always colourleſs. Common ſalt, for inſtance, with water, makes a colourleſs ſolution; but

Alkalis and acids, at the time they obtained the name of ſimple ſalts, were ſuppoſed to be really ſuch; modern diſcoveries, however, have now led to a different concluſion, and left no reaſon to doubt that all the acids, and at leaſt one of the alkalis, are compound bodies. The doctrine of the formation of acids is now fully elucidated; the

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but blue or green vitriol makes a blue or green ſolution with water. A mixture on the contrary is always muddy, and if left to ſtand, a ſediment will be depoſited. The point of *ſaturation* is when the fluid will hold no more of the ſolid body in clear ſolution, but *precipitates* it, or lets it fall to the bottom.

proceſſes of combuſtion, and of the calcination of metals, which were formerly attributed to the expulſion of an imaginary ſubſtance, called phlogiſton, are now proved to be only the formation of acids; or the union of the principle of acidity or oxygen contained in the atmoſphere, with ſubſtances, the particles of which have, in certain circumſtances, a ſtronger attraction for that principle, than it has for the matter of heat. The chief circumſtance which favours the union of the principle of acidity, which is alſo called by the French chemiſts oxygen, with other bodies, is a proper degree of heat; which, by removing the particles of bodies further from each other, diminiſhes their attraction, and allows room for the entrance of air into their interſtices. In the calcination of metals, and in combuſtion, the oxygen gas of the atmoſphere is decompoſed, and while the baſe is attracted by the inflammable ſubſtance or metal, the matter of heat is diſengaged, and becomes ſenſible. Bodies, however, may be acidified or oxygenated without being expoſed to the air; and this is performed by placing them in contact with bodies which are already united with oxygen, but which have a weaker attraction for that principle than the body which is to be acidified. It is upon this principle that metals are deprived of oxygen, or reduced to the metallic ſtate, by heating them in contact with charcoal, tallow, &c. In this caſe the inflammable ſubſtance having a ſtronger attraction for oxygen than the metal has, becomes oxygenated; while the metal, by being deprived of this principle, is reduced to the metallic ſtate. Metals and combuſtible bodies may alſo be oxygenated in the humid way, by ſubmitting them to the action of acids. In this proceſs the acid furniſhes the oxygen, and is therefore decompoſed. The oxygenation of minerals in the bowels of the earth is probably chiefly effected by the decompoſition of water, which is a compound of hydrogen and oxygen. A proceſs of this kind is continually carried on before our eyes; the ruſt which iron acquires by being expoſed to damp air is an oxygenation of that metal. Other metals, however, have leſs affinity with the principle of acidity, and this is remarkably the caſe with the perfect metals, platina, gold, and ſilver, which therefore do not become ruſted by expoſure to air.

In treating of ſalts, I ſhall firſt give an account of the alkalis, next of the acids, and laſtly of their combinations, or the neutral ſalts. I ſhall defer ſpeaking of the earthy and metallic ſalts till the earths and metals are deſcribed.

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ALKALIS.

Mineral fixed Alkali; where found.—Vegetable fixed Alkali; how obtained.—Uſe of the fixed Alkalis in the Arts.—Uſe of Alkalis in making Glaſs.—Proceſs of making Soap.—Volatile Alkali; how obtained; a compound Body.—Alkaline Air.

MINERAL fixed alkali, ſoda or natron, is the ſalt which is found recorded in ancient hiſtory under the name of nitre. It is ſaid to be found in Egypt in tolerably pure cryſtals, and alſo in Perſia, where it appears in a form reſembling that of hoar froſt. Even in Europe it is found in ſmall quantities in mineral ſprings, and alſo on the ſurface of new walls, in the form of a damp and dewy efflореſcence. In a compound ſtate it is found in abundance; it makes half the weight of common ſalt, and is alſo occaſionally found naturally combined with other acids. The mineral alkali cannot be obtained from the native ſalts containing it, without great labour and expence: what is uſed in the arts is procured by the incineration of certain plants growing near the ſea-ſide. The crude mineral alkali in commerce is called ſoda or barilla. Alkalis are either mild or cauſtic; the latter is their moſt ſimple ſtate, as when mild they are united with the carbonic acid, with which they form a kind of neutral ſalt. Though the carbonic acid has leſs affinity with the alkalis than any other acid, yet it is difficult to ſeparate it entirely. The uſual method of accompliſhing it is to diſſolve the mild alkali in water, to add to this ſolution ſome quick-lime, and then to filtrate the liquor, and evaporate it in cloſed veſſels; the ſaline ſubſtance left after evaporation is an alkali almoſt entirely deprived of carbonic acid. This proceſs is founded on the greater attraction which the carbonic acid has for quick-lime than for the alkalis.

The VEGETABLE fixed alkali, pot-aſh or kali, agrees in ſeveral circumſtances with the former. It is acrid when applied to the tongue, requires as great a degree of heat to melt it; and in a very ſtrong heat flies off totally in vapour. It differs from the foſſil alkali in having a much ſtronger attraction for water. This alkali may be cryſtallized, but not ſo eaſily as the foſſil. Little of the vegetable alkali has been found in a ſtate of nature, and that only as entering into the compoſition of nitre. It is obtained in conſiderable quantities from the aſhes of almoſt all land vegetables, by infuſing them in water; the liquid, when ſtrained from the dregs, will then contain the ſalt in a ſtate of ſolution, and by evaporation we obtain the alkali in a ſolid form. It is alſo eaſily obtained from a ſubſtance called tartar, which is depoſited by wine. The properties and uſes of the vegetable alkali are very ſimilar to thoſe of the mineral.

The fixed alkalis are employed in ſeveral of the arts, and particularly in that of making glaſs; for though many ſubſtances will fuſe the vitrifiable earths, and reduce them to a kind of glaſs, the alkalis are found the moſt effectual and convenient.

In the ſoap manufactory alſo the alkalis are a principal and eſſential ingredient. Common ſoap is indeed a combination of fixed alkali in a cauſtic ſtate with fat and oily matters. A very fine ſpecies of ſoap is formed by the union of mineral alkali with olive-oil, or oil of ſweet almonds. In the making of this ſubſtance, the alkali is firſt rendered cauſtic by boiling it with half its weight of quick-lime, which abſtracts its carbonic acid or fixed air by ſuperior attraction. What is called ſoap-leys is a ſolution of the cauſtic alkali in water, which is evaporated to ſuch a degree of denſity as to be able to ſuſtain a new-laid egg. To make the finer ſoap, a part of this lixivium is to be diluted, and mixed with an equal quantity of olive-oil. The mixture is put on a gentle fire, and agitated, by which the union is accelerated. When the mixture begins to unite well, the reſt of the lixivium is to be added to it, and the whole is to be digeſted with a gentle heat, till the ſoap is completely made. Good ſoap of this kind is white and firm when cold, and is not liable to become moiſt on expoſure to air; it is entirely miſcible with water, to which it gives a milky appearance, without exhibiting any particles of oil on the ſurface.

In the making of ſoft, liquid, green, or black ſoaps, cheaper oils are employed, as oil of nuts, of hemp, of fiſh, &c. but tallow is the ingredient uſed in our common hard ſoap.

Oil may be ſeparated from ſoap by the addition of an acid, without being much altered in its properties. On this account, waters which contain any acid, either in a diſengaged ſtate, or combined with any ſubſtance except fixed alkali, decompoſe ſoap, and will not completely mix with it.

In this decompoſition, eſpecially that effected by the vitriols of lime and magneſia, which are frequently contained in water, the vitriolic acid unites with the fixed alkali of the ſoap, and forms vitriol of ſoda, or Glauber's ſalt; the lime or the magneſia combines with the oil, and forms a kind of ſoap ſcarcely at all ſoluble, which floats in a whitiſh curd like maſſes on the ſurface of the water.

The VOLATILE alkali or ammonia is ſeldom or never found in a ſimple ſtate. It is met with in nature only compounded with other bodies, in nitrous ammoniac, or in common ſal ammoniac, which is ſometimes found in the neighbourhood of volcanoes, or coal-mines which have burnt for a long time. The volatile alkali of commerce is chiefly produced from bones. This alkali is very different in its properties from the other two; its volatility is ſo great, that under the ordinary preſſure of the atmoſphere it is continually flying off in a very pungent vapour. It is ſold in the ſhops under the name of ſmelling ſalts, ſal volatile, or ſpirit of hartſhorn. The proceſs of putrefaction in animal matters, and in ſome vegetables, particularly cabbages, throws it off into the air, together with other volatile matters, which in ſome meaſure diſguiſe its ſmell. Volatile alkali is now proved to be a combination of two other ſubſtances, namely, the baſes of the azotic and hydrogen gaſſes. M. Berthollet has found by analyſis that 1,000 parts of volatile alkali conſiſt of about 807 parts of azote, combined with 193 of hydrogen. The volatile alkali of the ſhops, that is in its mild and concrete ſtate, when heated to a certain degree, aſſumes the form of vapour, but by a diminution of the heat returns again to the concrete form. Volatile alkali, however, deprived of the fixed air which rendered it mild, is capable of receiving a permanently elaſtic form; in which ſtate it is called alkaline air. When a mixture of alkaline air and marine acid air was made by Dr. Prieſtley over mercury, a beautiful white cloud was formed, and a diminution in the bulk of the airs took place. The cloud having ſubſided, was found to be common ſal ammoniac, or a union of the volatile alkali with the marine acid. Nitrous air admitted to alkaline air, likewiſe occaſioned a whitiſh cloud, which ſoon diſappeared, leaving only a little dimneſs on the ſides of the veſſel. Fixed air admitted to alkaline air, produced a depoſition of the common or concrete volatile alkali, in the form of oblong and ſlender cryſtals, which croſſed each other, and covered the ſides of the veſſel like a net-work. Inflammable air admitted to alkaline air, produced no particular appearance. Water abſorbed the alkaline air, and left the inflammable air as before. Azotic gas ſeemed to have no effect on alkaline air. Alkaline air is abſorbed by water, in the proportion of $\frac{7}{8}$ of an ounce meaſure of air to 1 $\frac{1}{4}$ grains of rain-water; and the water is by theſe means made prodigiouſly ſtronger than any of the volatile ſpirit of ſal ammoniac or hartſhorn, obtained in the common way.

CHAP. III.

ACIDS.

Of Acids in general.—Vitriolic Acid; how obtained, &c.—Nitrous Acid; how obtained.—Muriatic Acid; how obtained, and its Uſe in the Arts.—Fluor Acid; diſſolves Glaſs; employed to make Etchings on Glaſs.—Acid of Borax.—Phoſphoric Acid.—Acid of Amber.

ACIDS are very active ſubſtances, and when concentrated are highly corroſive. They have ſo general a tendency to unite with other ſubſtances, that they are never obtained pure except by art. They are generally fluid, which ſeems, however, chiefly to be owing to their ſtrong attraction for water, of which few of them can be entirely deprived, and which they copiouſly attract from the atmoſphere. One of the marks by which the preſence of uncombined acids may be aſcertained, is their property of changing to a red, the blue colour of infuſion of violets, which alkalis change to a green. Acids are diſtinguiſhed into mineral, vegetable, and animal; the ſubject of this book will at preſent confine us to thoſe of the firſt claſs.

The acids found in the mineral kingdom are the carbonic acid or fixed air, the vitriolic, the nitrous, the muriatic, the acid of ſpar, the acid of borax, the acid of phoſphorus, and the acid of amber.

The CARBONIC acid has already been treated of under the head of gaſſes.

The VITRIOLIC acid takes its name from vitriol or copperas, from which it was formerly extracted by diſtillation. In the new chemical nomenclature, it is with much more propriety called the acid of ſulphur, as it is now found to be a combination of that inflammable ſubſtance with oxygen. The pungent and ſuffocating fumes which are produced by the inflammation of ſulphur, are an acid which is imperfect from a deficiency of oxygen; and which cannot be condenſed without the aid of water. The vitriolic acid can never be entirely deprived of water, but admits of the greateſt concentration of all the acids, and may be reduced to a ſtate in which its ſpecific gravity is double that of water. The denſe and ſluggiſh appearance of the concentrated vitriolic acid has given riſe to the improper name of oil of vitriol, under which it paſſes in the ſhops.

M. Lavoiſier makes a diſtinction between this acid, as it exiſts in an imperfect and gaſſeous ſtate, and as it exiſts in the form of a tranſparent and ponderous liquid combined with water. In its former ſtate he calls it, *acide ſulphureux* (ſulphureous acid); in the latter, *acide ſulphurique* (ſulphuric acid). The ſame difference of termination is employed to expreſs the different ſtates of the nitrous acid, according as it is imperfectly or completely ſaturated with oxygen. A difference of termination is alſo given to the combinations of acids, according as they are perfectly or imperfectly ſaturated with oxygen. Thus the combinations of the ſulphureous acid, are called *ſulphites*; thoſe of the ſulphuric acid, *ſulphats*, &c.

The vitriolic acid now uſed in commerce is prepared in the following manner:—A quantity of ſulphur and ſalt-petre, groſsly mixed, are placed in a veſſel within a ſmall room, lined with lead, and containing a few inches depth of water at bottom. The ſulphur is lighted, and the room cloſed. The ſalt-petre ſerves to maintain the combuſtion, by the oxygenous gas which it affords; and the acid fumes which are produced are abſorbed by the water. The proceſs is repeated till the water is thought ſufficiently acid. The volatile fumes are then diſſipated by expoſure to air, and the acid is concentrated by diſtilling off the ſuperfluous water.

The vitriolic acid is ſaid to have become concrete by cold, but it probably was not in its moſt perfect ſtate. It eaſily parts with its oxygen to inflammable ſubſtances; if oil is mixed with it, it is converted into a dark, viſcid ſubſtance, and emits ſulphureous and pungent vapours.

The vitriolic acid has been thought to exiſt in the atmoſphere, but this is a miſtake. It is diſcovered in ſome waters, but in ſmall quantity; it exiſts in ſome ores of metals, and makes one of the conſtituent parts of gypſum.

The NITROUS acid is a fluid of conſiderable weight, but does not admit of ſo much concentration as the vitriolic. In its moſt perfect form it is quite tranſparent and colourleſs, but in its ordinary ſtate it is of an orange tawny colour, and when expoſed to the air it conſtantly emits orange-coloured fumes, which are noxious. It very readily parts with its oxygen to inflammable ſubſtances and metals; and when mixed with oil of turpentine, it explodes and flames. The oil attracts the oxygen, and burns, while the azote is ſuddenly ſet at liberty, and occaſions the exploſion. When nitrous acid is diluted with an equal weight of water, it is called *aqua fortis*. The nitrous acid is conſiderably diffuſed in nature. All that is ſold in the ſhops is obtained by diſtilling ſalt-petre with the vitriolic acid.

Azotic and oxygenous gas were mixed together by Mr. Cavendiſh, and the electric ſpark was paſſed through them. In theſe trials a diminution of bulk was always obſerved; indeed five parts of oxygenous gas being added to three of common air, almoſt the whole diſappeared. By continuing his experiments, he found that an acid was produced, and that acid was the nitrous.

The MURIATIC acid, in its ordinary ſtate, is a yellowiſh-coloured fluid, and emits fumes which do not give the air a red tinge like the nitrous acid, but produces an appearance of miſt. Theſe fumes are noxious to the lungs, and ſmell like burning ſoot. The muriatic acid is diſtinguiſhed from the vitriolic and nitrous in the ſtrong adheſion of its component parts, which is evinced by its not parting with oxygen, and of courſe its having little action on inflammable ſubſtances. So ſtrong indeed is the attraction between the principles, whatever they are, which form this acid, that they have never been ſeparated. Its baſe therefore is wholly unknown to us, and we have no other evidence than analogy to lead us to conclude that, like other acids, it contains oxygen. M. Berthollet conjectures the radical of the muriatic acid to be of a metallic nature. The muriatic acid is by far the moſt abundant of all the acids in the mineral kingdom; it is naturally combined with lime, magneſia, and natron, or the foſſil alkali; with the latter it forms the immenſe beds of ſal gem, and the ſaline matter which gives ſaltneſs to the ocean.

As the muriatic acid can only ſubſiſt in the gaſſeous ſtate in the ordinary temperature and preſſure of the atmoſphere, it is neceſſary to uſe water in order to condenſe it. But the ordinary muriatic acid is capable of being combined with an additional quantity of oxygen, by being diſtilled with the mineral ſubſtance called mangane ſe, or with certain preparations of lead and mercury, which readily part with oxygen. The acid reſulting from this proceſs, and which is called oxygenated muriatic acid, can only, like the former, exiſt in the gaſſeous ſtate, and is abſorbed in a much ſmaller quantity by water. When the impregnation of water by this gas is carried beyond a certain point, the ſuperabundant acid precipitates to the bottom of the veſſel in a concrete form. M. Berthollet has ſhewn that this acid gas is capable of being united with a great number of ſalifiable baſes; the neutral ſalts which reſult from this union are capable of deflagrating with charcoal, and ſome of the metallic ſubſtances: theſe detonations are very violent and dangerous, from the great quantity of the matter of heat which the oxygen carries along with it into the compoſition of the oxygenated muriatic acid.

The muriatic acid in the oxygenated ſtate has alſo a remarkable power of rendering vegetable and animal matters white. The reducing of this principle to practice has, indeed, been productive of a very eſſential improvement in the art of bleaching, and for this too we are indebted to M. Berthollet*. By various experiments he was enabled to aſcertain that the oxygenated or dephlogiſticated marine acid, as it was at firſt called, only differs from the common marine acid, in containing a ſuperabundance of oxygen, with which it very readily parts. He diſcovered further, that oxygen has a remarkable property of deſtroying the colours of vegetable matters; that even the dew which falls from the atmoſphere, and that which comes from the nocturnal tranſpiration of plants, were impregnated with oxygen, ſufficiently to deſtroy the colour of paper, ſlightly tinged with tincture of turnſole. The ancient prejudices concerning the dew of the month of May, a ſeaſon when the tranſpiration of plants is moſt abundant, he conceives to have originated in a ſimilar obſervation.

Attributing, therefore, in his own mind the common effect of whitening linen in bleach-yards to the action of oxygen, he was led to imitate that proceſs by applying leys, and the oxygenated muriatic acid alternately, and by theſe means was enabled to make linen, &c. permanently white, by a very quick and eaſy proceſs. Obſerving further that it was the practice in common bleaching, to make the linen, &c. in the finiſhing, paſs through ſour milk, or a very weak mixture of the vitriolic acid with water; he alſo tried the paſſing of the cloth through a very dilute ſolution of the vitriolic acid, and obſerved that it was conſequently rendered of a clearer white.

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* Annales de Chymie.

The oxygenated acid may be employed either in the aerial form, or diluted with water; and the latter appears to be the moſt convenient mode of applying it. The effect ſeems to reſult entirely from the action of the oxygen which the acid parts with to the cloth, and which has a power of deſtroying vegetable colours. Perhaps the fading of dyed ſtuffs on being expoſed to the action of the light and air may be accounted for on the ſame principles. The acid which M. Berthollet employed in bleaching he found had parted with all its ſuperabundant oxygen to the cloth, and was reduced to the ſtate of the common muriatic acid. The ſoap-leys ſeem to act in two ways; by neutralizing any of the ſuperfluous acid which might be imbibed, it ſaves the cloth from being corroded; and it alſo prevents the ſuffocating fumes of the oxygenated acid from being offenſive or injurious. Poſſibly the detergent quality of the leys may have a further effect in carrying off the colouring particles which are detached from the cloth by the action of the oxygen.

When one or two parts of pale concentrated nitrous acid are mixed with four of fuming muriatic acid, an efferveſcence ſoon takes place, and oxygenated muriatic acid is produced; at the ſame time that the mixture becomes of a red colour. The mixed acid is called *aqua regia*, which has the property of diſſolving gold.

The SPARRY or fluor acid was diſcovered by Mr. Scheele, and takes its name from the ſubſtance from which it is obtained, and which is commonly known in England under the name of Derbyſhire ſpar. This acid when pure aſſumes the form of gas. In this ſtate it is heavier than atmoſpheric air, extinguiſhes flame, and deſtroys animal life; it has a penetrating ſmell, like that of marine acid, but more powerful; and its cauſticity is ſuch that it almoſt inſtantly corrodes the ſkin. Heat dilates it, without producing any other change. The addition of atmoſpherical air has the effect of producing with it a white vapour, which is more or leſs abundant, in proportion as the atmoſphere contains more or leſs of humidity.

If vitriolic acid is poured on the Derbyſhire ſpar, which is a combination of this peculiar acid with calcareous earth, and a gentle heat applied, the acid is diſengaged in an aerial form. It readily combines with water, and therefore the recipient ſhould be half filled with that fluid. The firſt experiments which were made of the diſtillation of this acid in glaſs veſſels, were attended with a ſtriking appearance, which required conſiderable acuteneſs for its explanation. It was obſerved that as ſoon as the acid gas reached the ſurface of the water, a quantity of earthy matter was depoſited. This was at firſt naturally attributed to the acid carrying over with it part of the calcareous ſtone from which it was diſtilled. Upon examination, however, it was found that the earth depoſited in the water was ſiliceous, and this gave riſe to an opinion that flint was only a compoſition of this acid with water. This hypotheſis was ſoon overturned, by obſerving that the glaſs veſſel in which the diſtillation was performed was always corroded, or in part diſſolved. In this manner it was found that the fluoric acid has the ſingular property of diſſolving glaſs. As only a moderate heat is required for the diſtillation of this acid, it is now uſual to make uſe of leaden veſſels for that purpoſe; which are not corroded by the acid. The baſe of this acid is unknown, as we are not acquainted with any ſubſtance which can abſtract its oxygen.

The fluoric acid has been ſucceſsfully employed to make etchings on glaſs, in the ſame manner as nitrous acid is applied to copper. It combines readily with earth and alkalies, but ſcarcely, if at all, acts on gold, ſilver, lead, mercury, tin, antimony, biſmuth, or cobalt, but it diſſolves their calces. It acts directly on iron and zinc, with the production of inflammable gas; and it likewiſe diſſolves copper in the metallic ſtate, though leſs eaſily than when calcined.

If BORAX is diſſolved to ſaturation in boiling water, and the vitriolic acid added in ſuch quantity as to be perceptibly in exceſs, a ſubſtance will riſe to the ſurface of the water in the form of white ſcales, which is proved to be a peculiar acid. Many chemiſts have ſuppoſed that this acid is an artificial product, formed by a combination of the ſalts made uſe of in its manufacture. This opinion, however, has now been given up, ſince this acid has been found to exiſt in a ſtate of great purity in mineral waters, and ſince real borax may be formed by adding this ſcaly ſalt to the mineral alkali. The acid of borax requires about fifty times its weight of water for its ſolution. In a moderate heat it melts with leſs intumeſcence than borax itſelf; and the glaſſy ſubſtance, thus formed, is again ſoluble in water, having only loſt its water of cryſtallization.

The acid of borax is uſed to fuſe vitrifiable earths, with which it forms clear and almoſt colourleſs glaſſes; by the aſſiſtance of heat it diſſolves the earth precipitated from what is called the liquor of flints. It unites with ponderous earth, magneſia, lime, and alkalis, and forms with theſe ſubſtances ſaline compounds. All theſe properties, and more eſpecially its taſte, the red colour it communicates to the tinctures of violets and turnſole, and its neutral combinations with alkalies, ſufficiently indicate its acid nature; but it is the moſt feeble of all the acids, and is diſengaged from its combinations even by the carbonic acid. The acid of borax is the ſubſtance called by Homberg ſedative ſalt, from its ſuppoſed effects on the human body. It efferveſces with a boiling hot alkaline ſolution, but not with metals or abſorbent earths, though it may be united with them. It has a weak attraction for inflammable ſubſtances, particularly ſpirits of wine, the flame of which it tinges green. From this circumſtance it has been ſuppoſed, but without ſufficient proof, to contain copper.

Phosphoric acid is obtained by the combuſtion of the bones of adult animals, which are afterwards pounded, and paſſed through a fine ſilk ſieve; a quantity of dilute vitriolic acid is then poured upon the powder, but leſs than is ſufficient for diſſolving the whole. This acid unites with the calcareous earth of the bones, and forms ſelenite, and the phoſphoric acid remains free in the liquor. The liquor is decanted off, and the reſiduum waſhed with boiling water; this water, which has been uſed to waſh out the adhering acid, is mixed with what was before decanted off, and the whole is gradually evaporated. The diſſolved ſelenite now cryſtallizes in the form of ſilky threads, which are removed; and by continuing the evaporation we procure the phoſphoric acid, under the appearance of a white pellucid glaſs. When this is powdered, and mixed with one third of its weight of charcoal, we procure very pure phoſphorus by ſublimation. The phoſphoric acid, however, as procured by the above proceſs, is never ſo pure as that obtained by oxygenating pure phoſphorus, either by combuſtion or by means of the nitrous acid.

The phoſphoric acid may be rendered concrete with very little difficulty, by merely exhaling the moiſture. It abounds in the animal kingdom, and is not unfrequent in the vegetable and mineral. In this laſt it is found united with lead and iron, as well as with calcareous earth.

The acid of AMBER is obtained from the ſubſtance of that name, by the ſimple application of heat. The operation muſt not be carried on too far, or by too ſtrong a fire, as the oil of the amber is apt to riſe with the acid. The acid is found in a concrete form in the neck of the ſubliming veſſel; it is ſoluble in twenty-four times its weight of cold water, and in a much ſmaller quantity of hot water. It poſſeſſes the qualities of an acid in a very ſmall degree, and only affects the blue vegetable colour very ſlightly.

CHAP. IV.

NEUTRAL SALTS.

The Union of an Acid and Alkali deſtroys the corroſive Quality of each.—Neutral Salts do not communicate the ſaline Quality to other Bodies.—Cryſtalline Form—how decompoſed.

NATURAL productions paſs by gradations into each other; and I might have given an account of the primitive earths immediately after that of the alkalies, as theſe ſubſtances have ſeveral properties in common, particularly that of uniting with acids, and forming neutral compounds. Metals alſo are capable of being united with acids, and of forming with them ſaline ſubſtances. A lucid order will however be better preſerved, by at preſent confining our attention to the conſideration of ſuch neutral bodies as are formed by the union of an acid and an alkali.

To a perſon unacquainted with chemiſtry, it is a ſtriking circumſtance that two acrid and corroſive ſubſtances ſhould by their union form a compound very mild and inactive. Such however is the caſe, and what is ſtill more remarkable, their previous acrimony, and tendency to combine, renders the neutral body proportionably more inoffenſive. Thus an alkali united with vitriolic acid, may be received into the body with much leſs caution than when combined with the aerial or carbonic acid. The neutral ſalts in general have not ſo ſtrong a taſte as the ſimple, their tendency to combination and their ſolubility being leſs conſiderable; but the criterion which more eſpecially diſtinguiſhes them from the former is, that they cannot, like the ſimple ſalts, communicate the ſaline properties to other bodies. Their cryſtalline form is likewiſe a circumſtance which very generally diſtinguiſhes the neutral from the ſimple ſalts. The volatility of the neutral ſalts is not in general ſo great as that of the ſimple ſalts.

Neutral ſalts may in many caſes be decompoſed by heat alone, but in general it is neceſſary to have recourſe to elective attraction, or the addition of a third ſubſtance. When the decompoſition is effected by heat alone, the more volatile part is forced off: but it ſeldom ſucceeds in this way, the ingredients adhering ſo ſtrongly that they riſe together. It then becomes neceſſary to have recourſe to elective attraction. Thus, if from a neutral ſalt we wiſh to obtain the acid pure, we apply another acid which has a greater attraction for the alkali. If our object is to obtain the alkali ſeparate, we apply a ſubſtance which has a ſtronger attraction for the acid.

CHAP. V.

VITRIOLIC SALTS.

Glauber's Salt; how decompoſed; Solution of it left to cool cryſtallizes on being ſhaken.—Vitriolated Tartar.—Vitriolated Ammoniac.

THE firſt ſubſtances of this kind which challenge our attention, are Glauber's ſalt and vitriolated tartar, or as they are denominated in the new chemical nomenclature, ſulphat of ſoda, and ſulphat of pot aſh. The former of theſe neutral ſalts is compoſed of the vitriolic acid, combined with the mineral alkali; and the latter of the ſame acid with the vegetable alkali. They both have a ſaline bitterneſs. By heat their ingredients may be raiſed into vapour, but no one ſimple ſalt will ſeparate them, as no acid has a ſtronger attraction for the alkali than the vitriolic, nor any alkali a ſtronger attraction for the vitriolic acid than the fixed. Dr. Stahl propoſed the effecting of this ſeparation as a problem. He knew how to ſolve it, and it was afterwards done by a double elective attraction. Another more curious method is this: take Glauber's ſalt or vitriolated tartar, melt the ſalt in a hot crucible, and add to it firſt a quantity of charcoal, which has a ſtronger attraction for the oxygen of the vitriolic acid than the latter has for the alkali. Theſe being expoſed to heat, the charcoal in part diſappears, and the mixture acquires a deep red colour. If the matter is poured out, we find it to be an *hepar ſulphuris*, or liver of ſulphur, the charcoal having carried off with it the oxygen in the form of carbonic acid gas.

GLAUBER'S SALT is more fuſible than vitriolated tartar, melting in a moderate degree of red heat. The ſolution of Glauber's ſalt forms into columnary cryſtals, which have generally ſix ſides, four principal, and two which ſeem accidental. Its cryſtals, containing a large quantity of water, are liable to have it abſtracted from them by the atmoſphere, when they fall to powder, or in chemical language *effloreſce.* How much water Glauber's ſalt is capable of containing, is known by its requiring twice its weight of water to cryſtallize. The water ſhould be added in a boiling ſtate, and the mixture boiled a little afterwards; it may be ſet by in a quiet place, and will be found cryſtallized the next day, or will ſuddenly aſſume that ſtate on being ſhaken. On cryſtallizing, a quantity of heat is perceived to be emitted by the ſubſtance paſſing from a fluid to a ſolid ſtate, and conſequently loſing ſome of its latent heat.

Of Glauber's ſalt, all that is uſed at preſent is produced by art. It is ſaid to be produced by nature in the waters of mineral ſprings, and of the ſea. But the ſalt found in them is uſually not Glauber's ſalt but Epſom ſalt, conſiſting of the vitriolic acid and magneſia. Glauber's ſalt is obtained by uniting the vitriolic acid with the mineral alkali of common ſalt, as happens in the proceſs for obtaining the muriatic acid.

VITRIOLATED TARTAR is diſtinguiſhed from Glauber's ſalt, by a leſs degree of fuſibility. It requires for its fuſion the ſtrongeſt fire. Its cryſtals are harder, but leſs bright, and do not contain ſo much water as thoſe of Glauber's ſalt. Hence they are not liable either to ſpontaneous effloreſcence, nor to watry fuſion, but, like other ſalts, which contain little water, attract it ſtrongly. This ſalt decrepitates * in the fire. Vitriolated tartar does not appear to be a foſſil ſalt; it is found in the juices of vegetables, and remains in their aſhes after they are burnt. What is uſed in dying and medicine, is obtained by art, moſt commonly by adding vitriolic acid to nitre, in order to diſlodge the nitrous acid.

One hundred parts of vitriolated tartar contain, according to Bergman, about 52 parts of fixed vegetable alkali, 40 of vitriolic acid, and 8 of water of cryſtallization.

The vitriolic acid combined with the volatile alkali is called AMMONIACAL VITRIOL, or ſulphat of ammonia. Ammoniacal ſalts, it is proper to remark, are ſo called from *ammon*, an Arabic word for ſand; or, as Pliny conjectures, from the temple of Jupiter Ammon, near which ammonia uſed to be found in great quantities, on account of the camels dung and urine brought thither. With reſpect to the general properties of ammoniacal ſalts, as their alkali is very volatile, they are unable to bear any great degree of heat without being converted into vapour, though much more than might be expected from their ingredients. They emit pungent fumes if a fixed alkali or lime is added to them, as theſe ſubſtances, having a ſtronger affinity with the acids, expel the volatile alkali.

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* In decrepitation the cryſtals burſt, and fall into powder, from the expanſion of the water which they contain, by the heat. This occaſions that crackling noiſe which common ſalt makes when thrown into the fire.

When ammoniacal vitriol is very pure, it has the form of needles, which, on careful examination, are found to be flattened priſms of ſix ſides, two of which are very broad, terminated by ſix-ſided priſms irregularly formed; but the whole figure of the cryſtallization is ſubject to conſiderable varieties. This ſalt is ſometimes in the form of quadrangular priſms, and is ſometimes obtained in very thin plates.

Its taſte is bitter and urinous; it is light, and very friable. It is ſcarcely changed by expoſure to air; it does not effloreſce like Glauber's ſalt, but on the contrary ſlightly attracts the humidity of the air. It is very ſoluble in water, two parts of cold or one of hot water being ſufficient to hold it in ſolution; it cryſtallizes by cooling; but the moſt perfect cryſtals are obtained by ſpontaneous evaporation. It likewiſe unites with ice, which it melts, producing at the ſame time an exceſſive degree of cold. It does not act on the earths, nor on magneſia; though this laſt, according to Bergman, ſeems to decompoſe it after a length of time.

If mild fixed vegetable alkali, that is alkali combined with the carbonic acid gas, is diſtilled with ammoniacal vitriol, a double decompoſition and combination take place. The vitriolic acid unites with the fixed vegetable alkali, and forms vitriolated tartar. The carbonic acid gas being at the ſame time volatilized, together with the volatile alkali, alſo in a ſtate of gas, both unite, and form an ammoniacal ſalt, which cryſtallizes in the recipient.

Ammoniacal vitriol ſeems not to exiſt in a ſtate of nature; nor is it uſed either in medicine or the arts.

CHAP. VI.

NITROUS SALTS.

Common Nitre; Phenomena attending its Deflagration with inflammable Subſtances.—Natural Hiſtory of Nitre.—Cubic Nitre.—Union of nitrous Acid with various Earths.—Nitrous Ammoniac.

COMMON NITRE, or nitrat of pot-aſh*, conſiſts of the vegetable alkali and nitrous acid. Nitre was unknown to the ancients; the ſubſtance which they diſtinguiſhed by that name was a foſſil alkali, for we are told by Pliny that it was detergent, and uſed in making glaſs. It is uncertain when nitre was diſcovered, but we find it mentioned in the earlieſt chemical writers. Nitre melts in a very gentle heat, and in a greater degree of heat totally evaporates. Cold water diſſolves one-ſixth of its weight; and hot water about its own weight of this ſalt. Its cryſtals are more regular than thoſe of any other ſalt (being priſms of ſix ſides) having very little water in their compoſition, and therefore not liable to ſpontaneous evaporation. Its moſt extraordinary property is its deflagration with inflammable ſubſtances, which happens from the decompoſition of its acid, by which a large quantity of oxygenous gas is ſet at liberty. To the production of this air is owing the rapid combuſtion

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* Commonly known under the name of ſalt-petre.

tion of mixtures of nitre and inflammable ſubſtances, as evinced in * gunpowder. When nitre is melted by itſelf, no particular effect takes place; but if charcoal is added to it in its melted ſtate, deflagration or detonation takes place. We are therefore not to conſider nitre itſelf as an inflammable ſubſtance, but only as affording the pabulum of fire. If we continue to add charcoal, we find that the effect becomes leſs and leſs, till it entirely ceaſes. What remains in the crucible is different from nitre, it requires more heat to keep it fluid, and upon examining it we find it a pure vegetable fixed alkali. The charcoal diſappears, becauſe it is converted into carbonic acid gas by being united with oxygen; and the other component part of nitrous acid, the azote, by being deprived of its oxygen, is alſo volatilized and diſperſed.

When the deflagration is performed with ſulphur inſtead of charcoal, the conſequences are conſiderably different. Like charcoal indeed, when ſulphur is added in a certain quantity, it will produce no further deflagration; but when ſulphur is uſed, the flame is inſupportable to the eye, and the appearance of inflammation is greater though the noiſe is leſs. If the reſiduum is diſſolved in water, it will readily cryſtallize, and is found to be vitriolated tartar. The reaſon that leſs exploſion is produced by ſulphur than charcoal is, that the former, when united with the oxygen of the nitre, becomes fixed; whereas charcoal united with the ſame principle

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* The reader will do well to conſult what has been ſaid reſpecting gunpowder in Book II.

is converted into gas, and eſcapes with violence. The formation of vitriolated tartar is owing to the production of vitriolic acid from the ſulphur and the oxygen, which combines with the fixed vegetable alkali.

The detonation of nitre is a nice teſt of the inflammability of bodies, as there are many which are found to have this property when added to nitre in a ſtate of fuſion, which exhibit no ſigns of it on ordinary occaſions.

Nitre exiſts in large quantities in nature, and is continually formed in inhabited places; it is found in great quantities upon walls which are ſheltered from the rain; and the Biſhop of Llandaff collected a conſiderable portion from the decayed mortar of an old barn.

There appear to be three principal circumſtances that promote its formation; the firſt is, the preſence of chalk, or any other calcareous earth, as appears by its being collected from walls covered with plaſter, or from the ruins of ancient edifices. This ſalt is likewiſe found perfectly pure in chalky earths. The Duc de la Rochefoucault obtained it, in the proportion of one ounce in the pound, from the chalk of Roche Guyon.

The ſecond circumſtance neceſſary for the production of this ſalt, is the putrefaction, or ſpontaneous decompoſition of vegetable and animal matters. It is a well known fact, that places which are moiſtened with animal liquids, or contain animal matters in a ſtate of putrefaction, ſuch as dunghills, ſtables, privies, &c. produce much nitre. This conſtant obſervation has been applied to the formation of artificial nitre-beds. Dry ditches are dug and covered with ſheds open at the ſides; theſe are filled with animal ſubſtances, ſuch as dung, the excrements of quadrupeds, or birds, with the remains of vegetables. Theſe matters are from time to time watered, eſpecially with water charged with animal or vegetable matters capable of putrefaction, and they are turned up to renew their ſurfaces from time to time. When the putrefaction is in an advanced ſtage, a ſmall portion of the matter is taken up and lixiviated, to aſcertain whether it contains nitre; and when it is found ſufficiently charged with that ſalt, the whole is lixiviated.

The third circumſtance, which, in the opinion of ſome, is ſuppoſed to favour the production of nitre, is the acceſs of air; this is the cauſe of the formation of the nitre found on walls; and for this reaſon it is that nitre-beds require to be frequently turned over, in order that the air may touch them in all points. The neceſſity of the acceſs of air is ſaid to be ſtill more evidently ſhewn by the nitre contained in chalk, as it is never found below a certain depth. When the three circumſtances here treated of are united, the production of ſalt-petre is very abundant. Nitre-beds ought always to be conſtructed on theſe principles.

The theory of the formation of nitre has not been long known. Glauber, and many other chemiſts ſince his time, ſuppoſed nitre to exiſt ready formed in vegetables, from which they imagined it to paſs into animal ſubſtances, and to become diſengaged by putrefaction; but it was ſoon perceived, that vegetables do not contain a ſufficient quantity of nitre to account for what is obtained from nitre-beds. M. Thouvenel, whoſe diſſertation on the formation of nitre was honoured with the prize of the academy, has made many experiments to diſcover its origin: he found, that the nitrous acid is formed by the combination of an elaſtic fluid, diſengaged from animal matters in a ſtate of putrefaction, and pure air. He has likewiſe diſcovered, that the nitrous acid, once formed, combines with calcareous earth, when any animal matters are made uſe of; and that the remains of vegetables are uſeful to afford the fixed alkali, which is the baſe of common nitre. But M. Thouvenel did not determine the nature of the gas, which is diſengaged from putrefying animal matters. It is to Mr. Cavendiſh that we are indebted for the proof that it is the ſame gas, which conſtitutes one of the principles of the atmoſphere, under the name of azote, or phlogiſticated air, or atmoſpheric mephitis. His experiment, wherein the nitrous acid was formed by the combination of this gas with vital air, by means of the electric ſpark, has been already mentioned.

Cubic Nitre, or nitrat of ſoda, conſiſts of the nitrous acid and the fixed mineral alkali. It reſembles common nitre in all its ſtriking qualities; almoſt its only difference is the form of its cryſtals, which is a paralellopiped. The cryſtals adhere ſo ſtrongly, that they are ſcarcely ever found diſtinct and regular. For the deflagration of cubic nitre, charcoal is moſt proper; when performed with ſulphur, Glauber's ſalt is produced.

Cubic nitre has not yet been found in nature, but is always produced by art. The ſhorteſt method is adding nitrous acid to foſſil alkali. Its taſte is cooling, and rather more bitter than that of common nitre. Fire decompoſes it; but it decrepitates, and does not ſo eaſily melt as common nitre; like that ſalt, however, it gives out vital air during its decompoſition. It is ſlightly deliqueſcent when expoſed to air. It is more ſoluble in cold water than the common nitre, two parts of water, at the temperature of ſixty degrees, diſſolving one of the ſalt. It is ſcarcely more ſoluble in boiling water, and therefore cannot be had in regular cryſtals, except by ſlow evaporation.

Siliceous earth combines with the baſe of this ſalt, and diſengages the nitrous acid; clay likewiſe ſeparates the acid, and affords a reſidue in the form of frit, which is porous and opake when a ſtrong heat has been applied. Ponderous earth decompoſes this ſalt, and diſengages the mineral alkali. Magneſia and lime do not ſenſibly change it. The vegetable fixed alkali has a ſtronger affinity with its acid than the mineral. This fact is very eaſily ſhewn. If a heated ſolution of cubic nitre is divided into two parts, and the cauſtic vegetable fixed alkali added to one of them, it will afford priſmatic cryſtals during its cooling; no cryſtals, however, will be obſerved in the other part, becauſe cubic nitre does not cryſtallize by mere cooling without evaporation.

The neutral ſalts hitherto examined produce no effect whatever on cubic nitre; if theſe ſalts are diſſolved together in the ſame water, they cryſtallize ſeparately, and each in its ordinary manner; the nitre and Glauber's ſalt by cooling; the vitriolated tartar and cubic nitre by evaporation. All theſe properties ſhew, that cubic nitre differs from common nitre.

Nitrous Ammoniac, or nitrat of ammoniac, is compoſed of the nitrous acid and volatile alkali. It is more ſoluble and more fuſible than the vitriolic ammoniac. When the heat is increaſed a little above what is neceſſary for its fluidity, it is converted into copious vapours. The degree of heat neceſſary for its fuſion is a little above that of boiling water; and if more heat is ſuddenly employed, it has the ſingular property of undergoing deflagration, though no inflammable ſubſtance ſhould be added to it, and even in a cloſe veſſel. This ſeems to depend on the decompoſition of the volatile alkali.

M. Berthollet having expoſed ammoniacal nitre to the action of heat in a pneumato-chemical and diſtilling apparatus, and having obſerved the phenomena of this operation more carefully than had been done before, remarks, that it is not a true detonation which takes place, but a ſudden and inſtantaneous decompoſition, in which part of the volatile alkali is entirely deſtroyed. The water obtained in the receiver contains a ſmall part of the nitrous acid diſengaged in proportion to the quantity of volatile alkali decompoſed; and the latter gives out phlogiſticated air or azotic gas. The liquid product of this operation being weighed, a greater quantity of water is found than exiſted in the ammoniacal nitre; and M. Berthollet thinks that this ſuperabundant water is formed by the union of the inflammable gas, which is one of the principles of the volatile alkali, with the vital air of the nitrous acid. The azotic gas, or other principle of the volatile alkali, which is ſix times more in quantity than the inflammable gas, is diſengaged and collected under the veſſels of the pneumatic apparatus.

This ſalt diſſolves readily in water, and in a very large quantity, but it has not ſo ſtrong an attraction for water as to be deliqueſcent. It may be decompoſed by the vitriolic acid, or either of the fixed alkalis. The nitrous ammoniac is contained in the juices of ſome plants, but it is uſually prepared by artificial combination.

CHAP. VII.

MURIATIC SALTS.

Sal Digeſtivus.—Common Salt.—Rock Salt.—Natural Hiſtory of Salt.—Saltneſs of the Ocean.—Uſes of common Salt in the Arts.—Sal Ammoniac.—Natural Hiſtory of Sal Ammoniac.

THE combinations of the muriatic acid with the alkalis are, 1ſt, SAL DIGESTIVUS, or muriat of pot-aſh, which has alſo been called the febrifuge ſalt of Sylvius, and is a compoſition of the muriatic acid with the fixed vegetable alkali. Its taſte is penetrating and bitter; its cryſtals cubical, but almoſt always confuſed and irregular. In the fire it decrepitates, that is, its cryſtals ſuddenly break and fly in pieces by the rarefaction of the water which enters into their compoſition. If the heat is then continued, and ſufficiently ſtrong, it melts, and is volatilized without decompoſition. It is not much altered by expoſure to the air; it is however ſlightly deliqueſcent. About three parts of cold water are required to hold one part of this ſalt in ſolution, and hot water does not diſſolve a greater quantity.

Clay appears to decompoſe this ſalt in part, for marine acid is obtained by diſtilling it with the clays found in the vicinity of Paris. This operation, however, in fact affords only a ſmall quantity of acid, and ſand ſeems to have a ſimilar effect. Ponderous earth ſeizes its acid, and ſeparates the alkali, according to Bergman. Magneſia and lime do not at all change it. The vitriolic and nitrous acids diſengage the muriatic acid with effervefcence. This ſalt is found in a ſtate of nature, but never in conſiderable quantities; it is found in ſea-water, and in the water of ſalt ſprings, and it exiſts, though rarely, in places where nitre is found; it is likewiſe met with in the aſhes of vegetables, and in animal fluids. It is not employed in the arts, and its bitter taſte prevents its being uſed for culinary purpoſes. In moſt of its properties, however, it is very ſimilar to common ſalt.

2d. COMMON OR MARINE SALT is compoſed of the muriatic acid and the mineral fixed alkali, and is therefore the *muriat* of *ſoda* of the new nomenclature. This ſalt requires a full red heat for its fuſion; ſoon after this it begins to evaporate in white fumes. It has a ſtrong attraction for water, ſo as to deliqueſce in a moiſt air. During evaporation, the cryſtals of this ſalt form at the top of the ſolution, contrary to thoſe of other ſalts, which form at the bottom. When the evaporation is carried on quickly, it forms into thin irregular cruſts, and this is the ſtate in which we commonly have it. When the evaporation is ſlow, it aſſumes the cubic form, and the ſmalleſt cryſtals are the moſt regular; but if examined accurately, one of their ſides will be found a little hollow. The larger cryſtals have a pyramidal hollow apex, with a broad baſe. This is owing to their ſuperior ſurfaces being dry when floating in the water, while their inferior ſurfaces are moiſtened. Hence, as all dry bodies have a repulſion for water, and as their inferior ſurfaces have a tendency to ſink, they are hollowed into little pits on the ſuperior ſurfaces.

This ſalt contains little water of cryſtallization, and decrepitates in the fire. If frequently diſſolved, evaporated, and dried, its quantity is more diminiſhed than that of any other ſalt. By decompoſition we obtain either its acid or its alkali. The old chemiſts uſed to obtain its acid by heat alone, but this is troubleſome, and requires veſſels capable of enduring great heat. It is moſt readily decompoſed by the vitriolic acid, which has the ſtrongeſt attraction for the alkali. The nitrous acid will alſo decompoſe it, but is more liable than the vitriolic acid to come over with the muriatic. Some water muſt be put into the retort with the vitriolic acid, otherwiſe the muriatic acid will come over in fumes ſo copiouſly as to burſt the veſſels. The quantity of the water ſhould be about half that of the vitriolic acid; one half of which ſhould be put into the receiver to condenſe the fumes of the muriatic acid, and the other half mixed with the vitriolic to prevent its too ſudden action. Glauber's ſalt remains after this operation, and this is the uſual way of preparing it. The way to decompoſe marine ſalt, ſo as to obtain its alkali, is, firſt to expel the muriatic acid by means of the nitrous; we thus obtain cubic nitre, which muſt be deflagrated to obtain the alkali. A better method, however, is to mix a ſolution of marine ſalt with cauſtic vegetable alkali; by evaporation muriat of pot-aſh is obtained, and the remaining water contains the mineral alkali, pure and diſengaged.

Common ſalt is the moſt uſeful of ſaline bodies; for though there are ſome which reſiſt putrefaction equally well, there is none which is ſo friendly and agreeable to the human ſtomach. Its agreeable qualities are not indeed confined to man; moſt other animals indicate a great fondneſs for it. The rock ſalt, or ſal gem, though only one form of common ſalt, does not melt ſo eaſily as the common cryſtals. The moſt remarkable mine of this ſalt is at Cracow, in Poland, where there is thought to be ſufficient to ſupply the whole world many thouſand years. In this mine there are houſes, chapels, and ſtreets of rock ſalt, which, when illuminated, afford a beautiful proſpect. This ſalt is alſo obtained from ſome ſprings. When found in the earth it is ſeldom cryſtallized in any regular form; it has various degrees of whiteneſs, and is often found coloured; in this latter ſtate it is more particularly called ſal gem, becauſe it often has the appearance and tranſparency of gems.

The ocean differs in ſaltneſs in different climates. It is ſalter towards the equator than near the poles. This ſeems to ariſe from the different quantities of water which are evaporated, in proportion to thoſe which fall in rain. One pound of ſea water in the Baltic yields about a quarter of an ounce of ſalt; near Holland half an ounce; and in the Britiſh ſeas about two ounces. Boyle has alſo obſerved, that in places of great depth the water is ſalteſt at the bottom.

In the voyage made towards the north pole in 1773, it was found, that the ſea-water at the Nore contained not quite one thirty-ſixth of ſalt; at the back of Yarmouth ſands, not quite one thirty-ſecond; off Flamborough Head, rather more than one twenty-ninth; off Scotland, rather leſs than one twenty-ninth; latitude 74°, at ſea, one twenty-ninth; latitude 78°, rather leſs than one twenty-eighth; latitude 80°, near the ice, not quite one thirtieth; latitude 80½°, under the ice, not quite one twenty-eighth; latitude 68°. 46, rather more than one twenty-eighth; latitude 65, at ſea, rather leſs than one twenty-eighth. Dr. Hales got only one twenty-ſeventh from water taken up in the Mediterranean, and one twenty-ninth from water taken up at the Nore. Dr. Rutty ſays, he procured one twenty-fifth from water taken up in latitude 65; one twenty-eighth from water taken up near Dublin; and one thirtieth from water taken up at Dungarvan; and Dr. Lucas, that he obtained one twenty-fifth from water taken up near Harwich. From other obſervations alſo it has appeared, that water from near Teneriff contained about one thirty-ſecond of ſalt, and that ſome from Saint Jago contained fully one-fourth. Further experiments are needed to aſcertain the ſaltneſs of the ſea in different latitudes with preciſion.

The ſalt commonly uſed for culinary purpoſes, and known by the name of bay-ſalt, is obtained from the water of the ſea by evaporation. This evaporation is in ſome places performed by the heat of the ſun, the water being let into ſhallow trenches, in order to expoſe as large a ſurface as poſſible. This method is practiſed in the ſouthern provinces of France, and on a very large ſcale near Aveiro in Portugal. In the northern provinces, where the heat of the ſun is not ſufficiently great, artificial fires are employed. In ſome ſalt-works theſe two methods are united; and in England, and countries where ſalt rock is plentiful, that ſubſtance is diſſolved in ſalt water, and then evaporated*. In very cold countries another method is employed to ſeparate the ſalt from ſea-water. The water is expoſed in trenches on the ſea-ſhore, where

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* 'A great quantity of rock ſalt is uſed at Northwich, in order to ſtrengthen their brine ſprings, and a much greater quantity is ſent coaſtwiſe to Liverpool, and other places, where it is uſed either for ſtrengthening brine ſprings or ſea water; much of this rock ſalt was formerly exported to Holland, and it is ſtill ſent to Ireland for the ſame purpoſe. Rock ſalt, and the white ſalt which is at Northwich, chiefly made from rock ſalt, is exported free from the ſalt duty; and I was informed, that the quantity, which is annually exported from Northwich, is ſo great, that if it paid the duty, it would bring in to government, a ſum not much ſhort of four hundred thouſand pounds a year. "According to the beſt accounts I have been able to procure, the groſs duty on ſalt made in South Britain, amounts annually to ſeven hundred thouſand pounds(*a*)." The duty on ſalt made at Northwich is about ſeventy thouſand pounds a year, or a tenth part of the whole duty(*b*).

'The Northwich rock ſalt is never uſed at our tables in its crude ſtate; and its application to the pickling or curing of fleſh or fiſh, or preſerving any proviſions, without its being previouſly refined into white ſalt, that is, without its being diſſolved in water, and boiled down into what is called white ſalt, is prohibited under a penalty of 40 *s.* for every pound

(*a*) Camp. Sur. of Brit. Vol. II. p. 26.

(*b*) Since I received this information, an additional duty of 10 *d.* a buſhel has been laid, in 1780, on ſalt. The whole duty now amounts to 4 *s.* 2 *d.* a buſhel, the buſhel weighing 56 lb. The makers of ſalt can afford, in moſt places, to ſell their ſalt, excluſive of duty, from 8 *d.* to 10 *d.* a buſhel.

pound of rock ſalt ſo applied. The pure tranſparent maſſes, however, of rock ſalt, might, probably, be uſed by us with our food, without any ſort of danger or inconvenience; at leaſt, we know that rock ſalt is ſo uſed, without being refined, both in Poland and in Spain. In the laſt of theſe countries, at Cordova in the province of Catalonia, there is a ſolid mountain of rock ſalt, between four and five hundred feet in height, and a league in circuit; its depth below the ſurface of the earth is not known (*c*). This prodigious mountain of ſalt, which has no mixture of other matter with it, is eſteemed ſo ſingular an appearance, that it is thought to militate very much againſt the opinion of thoſe, who would derive the origin of all the beds of rock ſalt, which are found under the ſurface of the earth, from the evaporation of ſalt water, left in ſubterraneous caverns, either at the deluge, or upon ſome more local commotions of the globe.

'The quantity of rock ſalt which may be diſſolved in a definite quantity, ſuppoſe a pint or 16 avoirdupoiſe ounces of water, is differently eſtimated by different authors. Boerhaave is of opinion that 16 ounces of water will not diſſolve quite 5 ounces of rock ſalt (*d*); Spielmann thinks that they will diſſolve 6⅔ ounces (*e*); Newmann agrees with Spielmann (*f*); Eller ſays, that 7 ounces of foſſile ſalt may be diſſolved in 16 ounces of water (*g*); laſtly, Hoffmann aſſures us, that 16 ounces of water will not diſſolve above 6 ounces of common ſalt (*h*). I

(*c*) Hiſt. Nat. de l' Eſpag. p. 406.—See an account of ſimilar mountains of rock ſalt, in Shaw's Travels, p. 229, and in Pliny's Hiſt. Nat. l. xxxi. c. 7.

(*d*) Chem. vol. I. p. 476.

(*e*) Inſt. Chem. p. 48.

(*f*) Newmann's Chem. by Lewis, p. 256.

(*g*) Obſ. Phy. Chem. L. ii. Ob. xvi.

(*h*) Ber. Mem. 1750.

have

where it forms ſo thin a ſtratum, that the cold of the atmoſphere acts powerfully in congealing it. As the

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have tried this matter with diſtilled and with common water, and in various degrees of heat, and cannot but be of opinion, that Hoffmann's experiment approaches neareſt to the truth; I never could diſſolve *quite* 6 ounces of rock ſalt in 16 ounces of water. It is not wholly improbable, that different ſorts of rock ſalt may differ ſomewhat with reſpect to their ſolubility in water.

If it be admitted, that 16 ounces of water can diſſolve 6 ounces of ſalt and no more, then we may be certain, that no brine ſpring, in any part of the world, can yield 6 ounces of ſalt from a pint of the brine. For brine ſprings are, ordinarily, nothing but water in which foſſile ſalt has been diſſolved; but a pint of the ſtrongeſt brine cannot contain ſo much ſalt as is contained in a pint of water, which has been ſaturated with 6 ounces of ſalt; for a pint of water, in which 6 ounces of ſalt have been diſſolved, is increaſed a little in bulk, it will do more than fill a pint meaſure, and the ſalt left in the ſurplus will ſhew, how much the ſalt, contained in a pint of the ſtrongeſt brine, falls ſhort of 6 ounces. Or, we may conſider the matter in the following manner, which will, perhaps, be more intelligible; 16 ounces of water, impregnated with 6 ounces of ſalt, conſtitute a ſaturated brine, weighing 22 ounces; if therefore we would know how much ſalt is contained in 16 ounces of ſuch brine, by the rule of proportion we may argue, that if 22 ounces of brine contain 6 ounces of ſalt, 16 ounces of brine will contain $4\frac{4}{11}$ ounces of ſalt. Hence we may infer, that the ſtrongeſt brine ſprings will not yield much above one quarter of their weight of ſalt (*i*).

Dr.

(*i*) —— Several pits at Northwich, and at Barton in Lancaſhire, contain no leſs than ſix ounces of ſalt upon ſixteen of brine, which is as large a proportion of ſalt as water will diſſolve. *Newm. Chem.* p. 212, Lewis's note. — The author the frozen part conſiſts of mere water, the fluid which remains is conſequently more concentrated.

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‘Dr. Leigh, who firſt ſhewed the manner of refining rock ſalt, informs us, that ſome of the ſtrongeſt ſprings at Northwich, gave ſeven or eight ounces of ſalt from a quart of brine; but a quart of brine weighs conſiderably more than 32 ounces, the weight of a quart of water; ſo that the Northwich, ſprings, from this account, do not yield a quarter of their weight. At Middlewich there is ſaid to be one ſalt ſpring, which is ſtronger than the reſt, this ſpring yields a *full fourth* part of ſalt (*k*), and hence it is, probably, fully ſaturated. We have an account in Kircher's works, of ſome famous brine ſprings in Burgundy, from which we learn, that one hundred pounds weight of the ſtrongeſt brine, gave twenty-five pounds, or juſt *one fourth* of its weight of white ſalt (*l*).

‘There are a great many brine ſprings in Cheſhire, Worceſterſhire, Staffordſhire, Hampſhire, and in other parts of Great Britain, ſome of which are ſufficiently rich in ſalt to be wrought with profit, others not. From what has been before advanced, the reader will readily comprehend that ſixteen tons of the ſtrongeſt brine conſiſt of twelve tons of water, and of four tons of ſalt; and that, in order to obtain theſe four tons of ſalt, the twelve tons of water muſt be, by ſome means or other, evaporated, ſo as to leave the ſalt in a concrete form. Suppoſe there ſhould be a brine, which in ſixteen tons ſhould contain fifteen tons of water, and only one ton of ſalt; yet it may chance, that ſuch a weak brine may be wrought with more profit than the ſtrongeſt; for the profit ariſing from the boiling of brine into ſalt, depends as

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author here is fallen, probably, into a little miſtake, by confounding a pound of water with a pound of brine; for if a pound or 16 ounces of water will only diſſolve 6 ounces of ſalt, a pound of the brine, thus formed, will only hold $4\frac{4}{11}$ ounces of ſalt.

(*k*) Philoſ. Tranſ. N° 53.

(*l*) Kerch. Mun. Sub. Tom. II. Cap. XI.

much

The operation is then completed by means of artificial heat.

Pure clay has very little action on marine ſalt. Ponderous earth decompoſes it, but lime and magneſia produce no effect. Common ſalt is uſed to vitrify the ſurface of ſome kinds of pottery. This is done by throwing a certain quantity of it into the furnace, where it is volatilized, and applies itſelf to the ſurface of the pottery. This is the kind of glazing uſed in the making of white Engliſh pottery. Common ſalt is alſo uſed in making glaſs, to render the glaſs whiter and clearer. It is alſo employed as a flux to facilitate the precipitation of metals

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much upon the price of the fuel uſed in boiling it, as upon the quantity of ſalt which it yields. Thus the ſea water, which ſurrounds the coaſts of Great Britain, is ſaid to hold ſeldom more than one thirtieth, or leſs than one fiftieth part of common ſalt; but fuel is ſo cheap at Newcaſtle, that they can evaporate thirty or forty tons of water, in order to obtain one ton of ſalt, and yet gain as much clear profit as thoſe do, who, in counties leſs favourably ſituated for fuel, boil down the ſtrongeſt brine.

'The advantage reſulting from ſtrengthening weak brine or ſea water, by means of rock ſalt, is very obvious. Suppoſe that the ſea water at Liverpool, where large quantities of rock ſalt are refined, would yield one ton of ſalt from forty-eight tons of water, then muſt a quantity of fuel ſufficient to evaporate forty-ſeven tons of water be uſed in order to obtain one ton of ſalt. But if as much rock ſalt be put into the forty-eight tons of ſea water, as can be diſſolved in it, then will the ſea water reſemble a brine fully ſaturated, each ſixteen tons of which will give four tons of ſalt, and the whole quantity yielded by the evaporation of forty-ſeven tons of water, will be twelve tons of ſalt.'

Watſon's Chem. Eſſ. vol. II. p. 41.

metals from the ſcoriæ, and to prevent their calcination from the contact of the atmoſphere.

3d. Common Sal Ammoniac is the muriat of ammoniac of the French chemiſts, and conſiſts of the muriatic acid united to the volatile alkali. This ſalt is converted into vapour before it melts, but may be brought into fuſion by being combined with other ſubſtances, or even uncombined, if properly confined. When thrown into the fire, it increaſes the flame, and tinges it with a blue colour, eſpecially the flame of charcoal. When the air is very moiſt, this ſalt deliqueſces. It is very remarkable for producing a great degree of cold when mixed with water.

If we wiſh to obtain the acid of ſal ammoniac, we may expel it by means of the vitriolic acid, but the fumes cannot be condenſed without great difficulty. For obtaining its alkali, the chemiſts generally employ the vegetable, as it is the cheapeſt. The quantity of vegetable alkali uſed is generally equal, but perhaps ought a little to exceed, that of the ſal ammoniac; the water is in general equal in weight to the alkali, and a volatile alkali ſufficiently ſtrong is obtained. The product is different, according to the mildneſs or cauſticity of the fixed alkali. When a mild fixed alkali is uſed, ſo much volatile alkali riſes, that Du Hamel and others thought part of the fixed alkali was volatilized, and roſe along with it. This however is found to be owing to the carbonic acid, which made part of the weight of the fixed alkali, being transferred to the volatile alkali.

The ſal ammoniac of commerce is in the form of cakes. It is prepared at Cairo from the ſoot of camels dung, which is burned there inſtead of wood. This ſoot is put into round bottles a foot and a half in diameter, terminated by a neck two inches high; each bottle contains about forty pounds of this ſoot, and affords nearly ſix pounds of the ſalt. Theſe veſſels are expoſed to the heat of a furnace which acts on their bottom, while the upper part, being cooler, ſuffers the ſalt to be condenſed there. When the operation, which occupies three days, is finiſhed, the bottles are broken and the ſalt taken out; it receives the form of the upper part of the ſubliming veſſel, and the cakes are therefore convex and unequal, with a protuberance on one ſide from the neck of the ſubliming veſſel.

Pomet has deſcribed a kind of ſal ammoniac in loaves, ſimilar to thoſe of ſugar with the point cut off, and which are imported into France by the way of Holland. This kind is made in the Eaſt Indies. ‘ Sal ammoniac is, however, now made in large quantities in Britain. The volatile alkali is obtained in an impure liquid ſtate from ſoot, or bones, or any other ſubſtance which affords it; to this the vitriolic acid is added, and the vitriolic ammoniac thus produced is decompoſed by common ſalt, by a double affinity, or elective attraction; the vitriolic acid combining with the mineral alkali, and the marine acid with the volatile alkali. The liquor therefore contains Glauber's ſalt and ſal ammoniac, which are ſeparated by cryſtallization; and the ſal ammoniac is ſublimed into cakes for ſale. Lord Dundonald extracts volatile alkali from pit-coal; but whether it can be afforded cheaper for the general purpoſes of commerce, than that of the above proceſs, is not, I believe, yet aſcertained.* '

The taſte of ſal ammoniac is penetrating, acrid, and urinous. The form of its cryſtals is a hexahedral pyramid. Cubical cryſtals are ſometimes, though rarely, formed in the middle of the concave and hollow parts of the loaves which are produced by ſublimation.

This ſalt poſſeſſes a ſingular property, namely, a kind of ductility, ſo that it rebounds under the hammer, and may be bended; a circumſtance which renders it difficult to pulveriſe it.

Sal ammoniac is not decompoſed by clay, and by magneſia very imperfectly. Lime, and likewiſe ponderous earth, ſeparate the volatile alkali, even without the aſſiſtance of heat. If ſal ammoniac is triturated with quick-lime, the ſtrong ſmell of alkaline gas is immediately perceived.

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* Fourcroy's Chemiſtry. Note of the Tranſlator.

CHAP. VIII.

COMBINATIONS OF THE OTHER MINERAL ACIDS;

Sparry Tartar.—Sparry Soda.—Borax; its Properties; its Uſe in the Arts.—Combinations of Salts with Metals.

THE combinations of the other mineral acids with the alkalies, have in general been very imperfectly examined, and I ſhall therefore be very brief in treating of them.

The SPARRY TARTAR, or fluat of pot-aſh of the French chemiſts, is compoſed of the acid of ſpar united to the vegetable alkali. It is always in a gelatinous form, and has ſo ſtrong an attraction for water, that it cannot be cryſtallized. According to Scheele, it is acrid, cauſtic, and deliqueſcent, when dried and melted; he compares it in this ſtate to the liquor of flints. It appears, that the fire diſengages the ſparry acid, and that the ſiliceous earth taken up by the acid melts into a ſoluble earth by means of the fixed alkali. This ſalt has not been applied to any uſe. Of the ſparry ſoda ſtill leſs is known; and the ſame may be affirmed of the ſparry ammoniac.

The combinations of the acid of borax have not attracted much more attention, except the ſubſtance from which this acid derives its name. BORAX, the borat of ſoda of M. Lavoiſier, is compoſed of a peculiar acid united to the mineral alkali. The form in which it is expoſed to ſale is that of cryſtals, very tranſparent, and containing a large proportion of water. When a ſmall quantity of borax is heated ſo as to diſſolve in its own water, it boils in a white foam; and when the water is diſſipated, the ſalt is found to have loſt much of its weight. By increaſe of heat, it undergoes a proper fuſion, and aſſumes the appearance of glaſs; but is diſtinguiſhed from that ſubſtance, by diſſolving and cryſtallizing again.

Borax may be decompoſed by means of the muriatic acid. It appears ſurprizing, but the fact is certain, that a quantity of acid of borax, though ſo weak an acid in its more obvious properties, will diſlodge, when heat is applied, both the nitrous and muriatic acids, and unite itſelf to their alkali. The reaſon ſeems to be, that the attraction of different ſubſtances for the ſame body is different in different degrees of heat. This again is to be attributed to a double elective attraction, in conſequence of the addition of the matter of heat. The coheſion of the nitrous and muriatic acids to their baſe, is ſo much weakened by their affinity with heat, or in other words, their tendency to aſſume the gaſſeous form, that the attraction of the boracic acid, which is more fixed, becomes ſuperior, and diſplaces them.

Borax, as imported from the Eaſt Indies, is very impure. When purified, it has a very regular form. Its cryſtals are ſix-ſided priſms, two of the ſides being commonly larger than the others, terminated by trihedral pyramids. Its cryſtallization is, however, ſubject to conſiderable varieties. It is ſtyptic, and acts ſtrongly on the tongue, and like alkalies it converts the ſyrup of violets to a green. Borax, expoſed to the air, loſes a ſmall part of its water of cryſtallization, and ſlightly effloreſces. It is ſoluble in twelve parts of cold and ſix of hot water. Its cryſtals may therefore be obtained by cooling; but the fineſt and moſt regular are formed by ſuffering the cold ſaturated ſolution to evaporate ſpontaneouſly in the ordinary temperature of the atmoſphere.

Borax is exceedingly uſeful in many manufactures. It is employed as an excellent flux in the art of glaſs-making, as well as in aſſays. It is advantageouſly employed in ſoldering, which it aſſiſts by promoting the fuſion of the ſolder, by ſoftening the ſurfaces of the metals, and by defending them from the action of the air.

Very little is known of the combinations of the acid of borax with the vegetable and volatile alkalies.

The phoſphoric acid, and the acid of amber, are capable of combination with the alkalies; but the reſults of theſe combinations are ſo little known, that I ſhall paſs them over in ſilence, and haſten to the conſideration of the earthy and ſtony ſubſtances.

Some ſaline, earthy, and metallic ſubſtances, have ſuch a relation to each other, that they are ſeparated with great difficulty, and adhere after repeated ſolutions and cryſtallizations. This circumſtance has given riſe to another diviſion of ſalts, which are denominated triple. As they do not, however, appear of ſufficient conſequence to be treated of under a ſeparate ſection, I ſhall merely enumerate them at the concluſion of the preſent. The moſt remarkable examples of this kind are, mineral alkali with calcareous earth; common ſalt with magneſia; vitriolated magneſia with iron; alum with iron; viriolated copper with iron; vitriolated copper with iron and zinc; vitriolated iron with copper; vitriolated iron with zinc; vitriolated iron with nickel.

CHAP. IX.

EARTHS IN GENERAL.

Five Kinds of Earth.—Definition of Earths.—Exceptions.—Other general Properties of Earths.—Calcareous Earth.—Magneſia.—Barytes.—Clay.—Flint.

IT is now generally agreed among chemiſts and mineralogiſts, that all the earthy and ſtony ſubſtances which compoſe the ſolid parts of this globe, are ultimately reſolvable into five ſimple and original kinds of earth; namely, lime or calcareous earth, magneſia, barytes or ponderous earth, argill or clay, and ſilica or flint *. Theſe ſubſtances agree in the following properties, which may be conſidered as the characteriſtics of all earthy ſubſtances. They are nearly inſoluble in water, are uninflammable, have not the metallic ſplendour, and their ſpecific gravity, compared with that of water, is not more than five to one. This definition, however, like that of ſalts, is not ſo preciſe as to be beyond the reach of criticiſm; becauſe there are ſome earths perfectly ſoluble in water, though but in ſmall proportions, and there are many in the internal parts of the earth which afford the ſtrongeſt

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* It has lately been ſuppoſed, that there exiſt ſeveral other diſtinct kinds of earth belonging to particular foſſils. This may very probably be the caſe; but experiments have not yet been ſufficiently multiplied to eſtabliſh the fact.

evidence

evidence that they have been in a ſtate of ſolution. But the definition, though not ſtrictly accurate, is proper in a general ſenſe. There is great difference of ſolubility between earths and ſalts, for a few grains of earth are ſufficient to ſaturate * a large quantity of water. There are two other circumſtances not included in the definition, which make part of the idea of an earthy ſubſtance; 1ſt, a great degree of fixedneſs; 2dly, a diſpoſition to form a glaſſy concretion when melted with other ſubſtances.

Lime, properly ſo called, is obtained by expelling the carbonic acid from calcareous ſubſtances by means of heat. *Calcareous earth* is in a tolerably pure ſtate in common quick-lime; but if it is required perfectly free from foreign admixture, it may be obtained by the following proceſs: If pounded chalk is ſeveral times boiled in diſtilled water, the remainder will conſiſt almoſt entirely of calcareous earth, combined with the carbonic acid. If diſtilled vinegar is added to the powder thus obtained, it will form a ſaline combination with the lime only, to the excluſion of all extraneous matter. To a ſolution of this, decanted from the impurities, mild volatile alkali being added, the alkali will unite with the vinegar, while the calcareous earth ſeizes the carbonic acid of the alkali, and falls to the bottom in the ſtate of a perfectly pure chalk. The carbonic acid may be driven off by heat, and calcareous earth is thus obtained in its moſt ſimple ſtate.

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* See note †, p. 1.

The relative weight of quick-lime to that of ſlaked lime is as 1,000 to 1,287. Every pound can imbibe four ounces four drams and fifty-three grains of water.

Calcareous earth is ſoluble in the nitrous and muriatic acids, and forms deliqueſcent ſalts. It is precipitated from its ſolutions by means of vitriolic acid, with which it forms a nearly inſoluble compound, called ſelenite, (or plaiſter of Paris.) Pure calcareous earth, or lime, is ſoluble in a ſmall proportion in water, with which it contracts great heat. It is infuſible without addition. It attracts the carbonic acid from the fixed alkalies, and by itſelf becoming mild renders them cauſtic. Its ſpecific gravity is 2,723.

Magneſia does not burn into a cauſtic ſubſtance like quick-lime, though it is deprived of its carbonic acid by the application of heat. It is ſoluble in ſeveral acids, and forms with the vitriolic the ſal catharticus amarus, or Epſom ſalt. When mixed with water, it ſhews a very ſmall degree of heat, but without any efferveſcence. It requires 7,692 times its weight of water for its ſolution. It is not precipitated from other acids by the vitriolic, as calcareous earth is. Its ſpecific gravity is 2,155.

Barytes is by far the moſt ponderous of the earths, from which circumſtance it derives its name.

With vitriolic acid it forms the ponderous ſpar, which is inſoluble in water; and its combinations with the nitrous and muriatic acids are alſo not very ſoluble, but with the acetous acid (or vinegar) it becomes deliqueſcent. Combined with carbonic acid, it is ſoluble in 1550 times its weight of water, when pure in 900 times. The ſpecimens of barytes naturally combined with carbonic acid are rare; it is more commonly found united with the vitriolic acid. From this the earth may be ſeparated by the following proceſs: Pound the ponderous ſpar, and mix it with twice its weight of fixed alkali; expoſe this mixture to a ſtrong red heat for about two hours. The acid quits the earth to unite with the alkali, forming a neutral ſalt, which may be waſhed away. The earth remains combined with carbonic acid, which may be diſpelled by heat. The ſpecific gravity of this earth, when pure, is 3,773.

Argill, or *clay*, is ſoluble in the vitriolic, nitrous, and muriatic acids, and forms alum with the firſt of theſe. If concrete volatile alkali* is added to a ſolution of pure alum, the alkali and acid unite, while the clay falls to the bottom, united with only a ſmall quantity of fixed air. The fluid muſt be abſtracted by decantation, and the precipitate waſhed with diſtilled water, and dried. Pure clay does not become cauſtic by burning, but is contracted in ſize, and becomes very hard. The ſpecific gravity of this earth is only 1,669.

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* The volatile ſalts in a ſolid ſtate.

The principal natural ſpecimens of argillaceous earth are boles, clays, marles, ſlates, and mica. In none of theſe, however, except the flag-ſtone, does the argill amount to half the weight of the whole ſubſtance. Silica abounds very much in common clays. Baked clays conſtitute all the varieties of bricks, pottery, and porcelain. If baked in a ſtrong heat, they give fire with ſteel.

Silica, or *flint*, is ſoluble in only one of the acids, the fluoric. In its indurated ſtate, it is always ſufficiently hard to ſcratch and ſtrike fire with ſteel. After being burnt, it does not fall to powder as the calcareous earth does. It produces no efferveſcence with acids. It may be diſſolved by the fixed alkalies, both in the dry and wet way. When alkali and flint are expoſed to the heat of a glaſs-houſe furnace, if the alkali is only half the weight of the ſilica, it produces a diaphanous and hard glaſs, but when the alkali is in double or triple the proportion, the glaſs deliqueſces of itſelf, by attracting the humidity of the atmoſphere; and forms what is called liquor of flints. This earth is perfectly diſſolved in that wonderful boiling water-ſpout, above ſixty feet high, at Geyſer in Iceland, where by cooling it forms a hard ſiliceous maſs. Pure ſiliceous earth is obtained by fuſing* clear quartz with four times its weight of fixed alkali, diſſolving the whole in diſtilled water, and precipitating the earth by an acid. Its ſpecific gravity is 2,650.

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* Melting by heat.

Mr.

M. Bergman has formed perfect ſiliceous cryſtals by diſſolving ſiliceous earth in the ſparry acid, and ſuffering it to cryſtallize ſlowly. It is probable that nature forms them in a long courſe of time from a ſolution or diffuſion of this earth in water.

Though the ſimple earths are all infuſible alone, yet they may readily be fuſed by mixture with each other. The calcareous earth is found to act as a menſtruum in diſſolving the other earths by heat; and when it has once acted on any earth, a compound menſtruum is formed, which acts ſtill more efficaciouſly in diſſolving other earths. Hence it is, that any three of the ſimple earths may be fuſed into glaſs, provided calcareous earth is one of the number.

Thus far it appeared neceſſary to premiſe concerning the general properties of the five ſimple earths in their ſeparate ſtate; but as their combinations are various, and their uſes in this laſt ſtate very important, it will be proper to treat of each on a more ample ſcale than the limits of a ſingle chapter would admit.

CHAP. X.

CALCAREOUS EARTHS.

Chalk.—Limeſtone.—Marble.—Marle.—Calcareous Spar.—Iceland Cryſtals.—Petrifactions.—Parts of Animals found in Marle, &c.—Gypſoms.—Great Varieties.—Alabaſter.—Fibrous Stone.—Mineral Glaſs.—Selenite.—Gypſeous Spar.—Plaiſter of Paris; how prepared.—Fuſible or Derbyſhire Spar.—Spars, how formed.—Beautiful Appearances in different Caverns.—Metallic Combinations with calcareous Earth.

CALCAREOUS earth is ſometimes found in the form of powder, but more frequently in that of a concrete ſubſtance called chalk, which differs with reſpect to the fineneſs of its particles and firmneſs of texture.

1. Chalk conſiſts of calcareous earth or lime, united with carbonic acid, and an union of the ſame principles alſo conſtitutes limeſtone and marble. Theſe ſubſtances only differ from common chalk in their degree of purity, or in the manner of their aggregation, admitting of more or leſs poliſh. The different coloured veins in marble are produced by the admixture of other ſubſtances, (moſt commonly iron) unequally diſtributed through the maſs.

2. Strata of marle alſo contain calcareous earth, more or leſs blended with a conſiderable proportion of clay and ſand.

3. Calcareous earth is often found projecting into the interſtices and crevices of rocks in a cryſ-

tallized ſtate, and is then called calcareous ſpar. It is more or leſs tranſparent, and ſhivers into flat fragments of a rhomboidal figure. One variety is called Iceland cryſtals. They engaged the attention of Sir Iſaac Newton, by their remarkable quality of refracting the rays of light without ſeparating them into colours, ſo as to make a line drawn on paper appear double, when viewed through them. The Engliſh lead-mines are full of ſpars; their ſhape is in general a firm column, terminated at each end with a pyramid. Of theſe calcareous ſpars there are many varieties.

4. Calcareous earth appears in the form of animal and vegetable ſubſtances, petrified into ſtone by being expoſed to petrifying waters. Theſe fill up the pores of the ſubſtance with calcareous earth, and incruſt them. Hence we may conclude, that this earth is ſoluble in water, and is depoſited in certain circumſtances. The quantity of earth, however, contained in the water is very ſmall, and therefore the petrifactions are formed ſlowly. Thoſe organic bodies which reſiſt putrefaction moſt, are frequently found petrified, ſuch as bones, ſhells, and the harder kinds of wood; on the contrary, the ſoft parts of animals, which are very ſubject to putrify, are ſcarcely ever found petrified. Mr. Kirwan remarks, that petrifactions are moſt commonly found in ſtrata of marle, chalk, limeſtone, or clay; ſeldom in ſand-ſtone, ſtill more rarely in gypſum, but never in gneiſs, granite, baſaltes or ſhoerl; they ſometimes occur among pyrites and ores of iron, copper, and ſilver, and

almoſt always conſiſt of the ſpecies of earth, ſtone, or other mineral, which immediately ſurrounds them. Thoſe of ſhells are generally found neareſt the ſurface of the earth, thoſe of fiſh deeper, and thoſe of wood deepeſt. A very remarkable circumſtance is, that petrifactions are found in climates where their originals could not have exiſted. From the gradual and inſenſible concretion of this kind of matter from dropping waters, are formed the large pendulous columns hanging like icicles from the roofs and ſides of caves. The moſt remarkable are in the Peak of Derbyſhire. Sometimes they are found in the arches of old bridges, and ariſe from the water oozing through and carrying particles of lime with it. This earth ſo concreted is called ſtalactites, ſtone-icicles, or drop-ſtone.

5. The ſhells of all cruſtaceous animals, from the coarſeſt to the pearl which lines the ſhell of the oyſter, are all made up of this calcareous earth, with a ſmall quantity of animal gluten. Egg-ſhells are of the ſame nature, and thoſe marine bodies which, from their hardneſs and vegetable appearance, are called ſtony plants, ſuch as are all the ſpecies of coral, &c.

Marles, which have been already mentioned as containing calcareous earth, are generally divided into three kinds. Firſt, ſhell-marle; ſecond, clay-marle; third, ſtone-marle. The firſt is found in beds of conſiderable extent, and conſiſts of the remains of ſea and land ſhells; that which contains the ſea ſhells is commonly found in the greateſt quantity.

Of this kind is that of Paris, mentioned by M. Reaumur, which is about ten feet deep, and of great extent, conſiſting of oyſter and other ſea ſhells. The relics of land ſhells are thoſe of ſnails; they have probably been carried by the current of ſome water, and depoſited at one place, and the water being drained off, the ſhells remained behind. Beds of freſh-water ſhells are alſo found. Clay-marle is a calcareous matter, which when expoſed to the air crumbles to duſt; it is to be diſtinguiſhed from common clay, by effervescing with acids, from the calcareous earth it contains. Stone-marle differs from clay-marle only in being much harder; but it differs from ordinary ſtone by breaking to pieces when expoſed to the air.

It has been ſuppoſed by ſome reſpectable writers, that all theſe ſpecies of calcareous earth derive their origin from ſhells. Some marbles are evidently formed of ſhells, and thoſe of Derbyſhire exhibit this appearance in a remarkable manner. Coral is univerſally allowed to be the work of ſmall animals of the polypus kind. The ſtrata of limeſtone being alſo found ſo frequently united with ſhells and other marine ſubſtances, has induced the philoſophers to whom I allude to believe, that the ſtone itſelf is altogether compoſed of ſhells, which at firſt mouldered into paſte, and were afterwards preſſed and concreted together. In one of the quarries of Italy, the bones of ſmall fiſhes are found; and ſome rocks in the midland counties of England are almoſt wholly compoſed of the kind of ſhells called *entrochi*. The animals which produce the coral are here ſeldom to be found; but in other parts, as in Jamaica, the bottom of the ſea is entirely covered over with coral, and harbours are ſometimes ſtopped up with it. Sir Hans Sloane mentions a Spaniſh plate-ſhip, which was wrecked, and remained at the bottom of the ſea twenty-five years, being then fiſhed for, the treaſure, as well as the timber, &c. were covered with coraline concretions. Hence, this conſtant growth at the bottom of the ſea may in time produce beds and ſtrata of this kind of earth, which, according to circumſtances, may be converted into marle, limeſtone, marble, &c. Calcareous earths, united with carbonic acid, may be known under all forms, by effervеſcence with the mineral acids.

6. If vitriolic acid is poured on chalk, the carbonic acid is expelled, while the vitriolic unites with the calcareous earth, and conſtitutes a ſubſtance which has very little ſolubility. This is GYPSUM, ſelenite, or plaiſter of Paris, which exiſts in conſiderable quantities in nature. Gypſums are found in ſolid maſſes, very ſoft, and eaſily ſcraped with a knife. They are diſtinguiſhed from the combinations of calcareous earth with carbonic acid, by not effervеſcing with acids; and from other earthy bodies, by being by heat changed into a white powder, which when mixed with a large proportion of water, ſuddenly concretes into a ſtony maſs. They are moſt commonly found in the ſtrata of clay, ſometimes in thoſe of ſand, under the appearance of a whitiſh coloured maſs, but the ſmall pieces are tranſparent, and ſometimes have a red tinge. They are often compoſed of ſmall ſhining par-

ticles, like the grains of ſugar, and when under this appearance they are particularly called gypſum. When hard, ſo as to admit of being cut into toys and figures, they are called alabaſter. The ſecond form under which they are found, is that of a fibrous ſtructure of oblique cryſtals, which are parallel to themſelves, but which croſs the maſs from the upper to the under ſurface. In this ſtate they are called fibrariæ or fibrous ſtone by Dr. Hill. Theſe differ much in ſize and regularity of concretion. The third ſpecies is compoſed of clear tranſparent plates like glaſs, in cloſe contact with each other, but which may be ſeparated. They ſplit with a knife into fine plates, very flexible, though they cannot be bent without producing flaws. They are called glacies marina, and ſometimes Muſcovy glaſs, but improperly, as that is a different ſubſtance.

The fourth ſpecies is in the form of ſeparate oblong cryſtals, which are called ſelenites: ſome are long and regular, like cryſtals of ſalt. The fifth ſpecies of gypſeous ſpar is of a platey texture. Gypſeous ſpar varies in compactneſs and tranſparency, is ſometimes white, ſometimes reddiſh, and is mixed with a greater or leſs quantity of other matter: ſometimes we meet with it in cryſtals. The ores of metals are often found in this ſpar.

Sixthly, gypſum is often met with in waters of ſprings in a diſſolved ſtate; for we find by experiment, that it is ſoluble in water, though but in ſmall quantity. When the water is evaporated, it is depoſited in cryſtals very ſmall, and which appear like a white powder; but by the microſcope are found to be oblong regular concretions.

Margraff firſt ſhewed that all theſe ſpecies were compoſed of calcareous earth and vitriolic acid. He took a quantity of gypſeous earth in a ſubtile powder, and boiled it for ſome time in a ſolution of fixed vegetable alkali; and upon examination, he found the calcareous earth at the bottom in an uncombined ſtate, and in the ſolution a vitriolated tartar. He alſo compoſed an artificial gypſum of calcareous earth and the vitriolic acid, which had all the properties of a natural gypſum. From knowing the compoſition of theſe ſubſtances, we may ſufficiently underſtand their properties, particularly that of being converted by a moderate heat into plaiſter of Paris. If the purer kinds are reduced to fine powder, and put into an iron veſſel, by the time the veſſel is heated the powder grows light, and is thrown into motion like a boiling fluid. There are alſo a variety of other earthy powders, which when moiſt give the ſame appearance; for the vapour riſing up, makes its way through the powder, keeps it afloat, and agitates it like a liquid in a boiling ſtate. This appearance continues till moſt of the water is evaporated. After this the powder becomes heavy, and lies at the bottom of the veſſel as before heating. It is then prepared for plaiſter of Paris, for if a quantity of it is put into ſo much water as gives it the conſiſtence of cream, it will ſoon become ſolid, and ring like a veſſel of earthen-ware, or metal. It loſes its tranſparency by heat, and becomes white. The ſofter kinds are beſt for the plaiſter of Paris.

The explanation of all theſe phenomena is not difficult, when we conſider the nature of gypſum, which being a ſaline compound, has all the qualities of a ſalt. In its natural ſtate it is cryſtallized in conſequence of its containing a quantity of water. Heat expels the water; which being again added, is attracted by the gypſum, and occaſions a cryſtallization.

A more violent heat produces very little change, as the vitriolic acid adheres very cloſely to the earth. If theſe ſubſtances, however, are mixed in powder with a quantity of charcoal-duſt, the whole of the acid may be diſſipated, and the calcareous earth only left behind, and thus a particular phoſphorus is formed. In this experiment the charcoal attracts the oxygen of the acid, which is by that loſs rendered volatile, and is diſperſed in fumes.

7. Calcareous earth is alſo found ſaturated with muriatic acid in ſea-water and in ſalt-pits.

8. Calcareous earth, united with the fluoric acid, forms the fuſible ſpar or fluor, which is commonly known by the name of DERBYSHIRE SPAR. The texture of this compound is either ſparry, or irregularly ſhattered or cracked. It is either tranſparent or opake; and the ſpecimens are of a cubic, rhomboidal, polygonal, or irregular figure. The coloured ſpars have the property of emitting light when laid on a hot iron, or otherwiſe heated; but they loſe this property by being made red hot. The

green ſpars are the moſt phoſphoreſcent, but none of them exhibit this quality except when well warmed. They are ſcarcely harder than common calcareous ſpars, and therefore do not ſtrike fire with ſteel. They do not melt by themſelves; but very much promote the fuſion of other ſtones, particularly the calcareous. They do not efferveſce with acids, either before or after being ſubmitted to the action of fire.

Mr Whitehurſt explains in the following manner the formation of ſparry and ſtalactitical productions. When water impregnated with the ſparry acid proceeds ſlowly through different ſtrata of earths and minerals, it becomes charged with a variety of theſe ſubſtances in ſolution; and as it exudes gradually on the ſurface of caverns and fiſſures, the aqueous particles evaporate, and the ſparry matter cryſtallizes in various forms, including in its own ſubſtance the heterogenous matters with which it is charged.

If the quantity of water thus impregnated, which exudes through the pores of the earth or ſtone, is not more than will eaſily evaporate in the ordinary heat of the atmoſphere, a ſparry cruſt is formed. If the quantity of water exuded exceeds the quantity evaporated, ſtalactites are produced in one inſtance, and tubes in another.

If a drop of water hangs from the roof, almoſt dropping, the aqueous particles evaporate from the ſurface ſooner than from its interior parts. A cryſtallization therefore takes place on the ſurface, while the center remains fluid: the water thus detained is continually increaſing, and the tube gradually extends downwards. By this proceſs, tubes are frequently formed of two feet in length, and one tenth of an inch in diameter. The appearance of caverns ornamented with theſe ſplendid productions exceeds that of the moſt laboured works of art: tranſparent columns, adorned with the moſt beautiful and vivid colours, diſpoſed ſometimes in the form of a honey-comb, ſometimes in a more irregular arrangement: mirrors, reflecting the images of objects, tinged with a light ſhade of the moſt delicate colours, raviſh the eye of the beholder. The pillars appear of various forms and ſizes; ſometimes arranged like a regular colonnade, and ſometimes diſpoſed with all the delightful irregularity of nature. The ſtalactites hang like icicles from the lofty roofs of theſe ſtupendous caverns, and are reflected back by the poliſhed and glittering floors. Some of the moſt ſtriking caverns of this kind are the grotto of Antiparos*, Poole's Hole, and Peak Hole in Derbyſhire.

9. Calcareous

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* The following is an account of this famous grotto, communicated by Magni, an Italian traveller, to the celebrated Kircher.—'Having been informed (ſays he) by the natives of Paros, that in the little iſland of Antiparos, which lies about two miles from the former, a gigantic ſtatue was to be ſeen at the mouth of a cavern in that place, it was reſolved that we (the French conſul and himſelf) ſhould pay it a viſit. In purſuance of this reſolution, after we had landed on the iſland, and walked about four miles through the midſt of beautiful plains, and ſloping woodlands, we at length came to a little hill, on the ſide of which yawned a moſt horrid cavern, that with its gloom

at

9. Calcareous earth is found ſaturated with a particular acid, perhaps of the metallic kind, namely, the

at firſt ſtruck us with terror, and almoſt repreſſed curioſity. Recovering the firſt ſurpriſe, however, we entered boldly; and had not proceeded above twenty paces, when the ſuppoſed ſtatue of the giant preſented itſelf to our view. We quickly perceived, that what the ignorant natives had been terrified at as a giant, was nothing more than a ſparry concretion, formed by the water dropping from the roof of the cave, and by degrees hardening into a figure that their fears had formed into a monſter. Incited by this extraordinary appearance, we were induced to proceed ſtill farther, in queſt of new adventures in this ſubterranean abode. As we proceeded, new wonders offered themſelves: the ſpars, formed into trees and ſhrubs, preſented a kind of petrified grove; ſome white, ſome green; and all receding in due perſpective. They ſtruck us with the more amazement, as we knew them to be mere productions of nature, who, hitherto in ſolitude, had, in her playful moments, dreſſed the ſcene, as if for her own amuſement.

'But we had as yet ſeen but a few of the wonders of the place; and we were introduced only into the portico of this amazing temple. In one corner of this half illuminated receſs, there appeared an opening of about three feet wide, which ſeemed to lead to a place totally dark, and that one of the natives aſſured us contained nothing more than a reſervoir of water. Upon this we tried, by throwing down ſome ſtones, which rumbling along the ſides of the deſcent for ſome time, the ſound ſeemed at laſt quaſhed in a bed of water. In order, however, to be more certain, we ſent in a Levantine mariner, who, by the promiſe of a good reward, with a flambeaux in his hand, ventured into this narrow aperture. After continuing within it for about a quarter of an hour, he returned, bringing ſome beautiful pieces of white ſpar in his hand, which art could neither imitate nor equal. Upon being informed by him that the place was full of theſe beautiful incruſtations, I ventured in once more with him, for about fifty paces, anxiouſly and cautiouſly deſcending by a ſteep and dangerous way. Finding, however, the tungſtenic acid. This combination forms the TUNGSTEIN of the Swedes. This ſtone is remarkably heavy,

however, that we came to a precipice which led into a ſpacious amphitheatre, if I may ſo call it, ſtill deeper than any other part, we returned, and being provided with a ladder, flambeaux, and other things to expedite our deſcent, our whole company, man by man, ventured into the ſame opening, and deſcending one after another, we at laſt ſaw ourſelves all together in the moſt magnificent part of the cavern.

‘Our candles being now all lighted up, and the whole place completely illuminated, never could the eye be preſented with a more glittering, or a more magnificent ſcene. The roof all hung with ſolid icicles, tranſparent as glaſs, yet ſolid as marble. The eye could ſcarce reach the lofty and noble ceiling; the ſides were regularly formed with ſpars; and the whole preſented the idea of a magnificent theatre, illuminated with an immenſe profuſion of lights. The floor conſiſted of ſolid marble; and in ſeveral places, magnificent columns, thrones, altars, and other objects appeared, as if nature had deſigned to mock the curioſities of art. Our voices, upon ſpeaking or ſinging, were redoubled to an aſtoniſhing loudneſs; and upon the firing of a gun, the noiſe and reverberations were almoſt deafening. In the midſt of this grand amphitheatre roſe a concretion of about fifteen feet high, that, in ſome meaſure, reſembled an altar; from which, taking the hint, we cauſed maſs to be celebrated there. The beautiful columns that ſhot up round the altar, appeared like candleſticks; and many other natural objects repreſented the cuſtomary ornaments of this ſacrament.

‘Below this ſpacious grotto, there ſeemed another cavern; down which I ventured with my former mariner, and deſcended about fifty paces by means of a rope. I at laſt arrived at a ſmall ſpot of level ground, where the bottom appeared different from that of the amphitheatre, being compoſed of ſoft clay, yielding to the preſſure, and in which I thruſt a ſtick to about ſix feet deep. In this, however, as above, numbers of the moſt beautiful cryſtals were formed; one of which, heavy, and reſembles fluor ſpar in the form of its fragments. It becomes yellow in acids, and is found united with petroleum (or mineral pitch) in the proportion of ninety-five of the former to four of the latter. In this ſtate it forms the ſwine-ſtone, which is of a dark colour, and becomes fetid by friction.

10. Calcareous earth is alſo found united with three of the metals, iron, copper, and lead; of each of which there are ſeveral varieties. When united with copper, it is called mountain blue; when united with calx of copper, it is denominated Armenian ſtone. Gypſeous earth combined with calx of copper, is called turquoiſe and malachites. The pureſt malachite, according to Kirwan, contains ſeventy-five parts of copper and twenty-five of aerial or carbonic acid; calcareous earth is therefore not an eſſential ingredient. It is of a green colour, and is ſometimes cut and poliſhed as a gem.

which, particularly, reſembled a table. Upon our egreſs from this amazing cavern, we perceived a Greek inſcription upon a rock at the mouth, but ſo obliterated by time, that we could not read it. It ſeemed to import that one Antipater, in the time of Alexander, had come thither; but whether he penetrated into the depths of the cavern, he does not think fit to inform us.'—*Kircher de Mund. Sub.* 112.

CHAP. XI.

MAGNESIAN EARTHS.

Magneſia, how obtained.—Epſom Salt.—Soap Rock.—French Chalk.—Serpentine Stone.—Mica.—Talk.—Muſcovy Glaſs.—Aſbeſtos.—Mineral Cloth.—Mountain Leather.—Mountain Flax.—Mountain Wood.

TO obtain MAGNESIA, the mother water of nitre, or of common ſalt, is placed in a large veſſel, and diluted with a conſiderable quantity of common water. Fixed alkali diſſolved in water is then added, and the mixture juſt made to boil. By this proceſs the magneſia falls to the bottom of the veſſel in the form of a powder, which is purified by repeated affuſions of water. Magneſia, in its mild ſtate, conſiſts of forty parts magneſian earth, forty-eight carbonic acid, and twelve water. The cryſtallized aerated magneſia contains half its weight of carbonic acid, one fourth magneſian earth, and one fourth water.

Magneſia combined with vitriolic acid conſtitutes EPSOM SALT, which in many reſpects reſembles Glauber's ſalt; it may be diſtinguiſhed, however, by an eaſy experiment; for if a fixed alkali is added to a ſolution of Epſom ſalt, a precipitation is produced, which is not a conſequence of adding an alkali to a ſolution of Glauber's ſalt. Even the volatile alkali, if mild, is capable of ſeparating magneſia from its acid, by means of a double attraction; the alkali unites with the vitriolic acid, and part of the earth falls to the bottom, combined with carbonic acid.

Magneſia enters into the compoſition of ſome earthy ſubſtances; the ſtones uſually treated of under this head conſiſt of magneſia united with flint; but the latter uſually predominates. Moſt of them are ſoapy to the touch, and ſo ſoft that they may be cut into various utenſils.—Of theſe the following are the moſt remarkable:

1. Steatites, lapis ollaris, or SOAP ROCK, is of various colours, but chiefly different ſhades of green. It does not become ductile in water, and is fuſed with difficulty. One variety of it is in the form of ſix-ſided priſms, another is lamellated.

2. Smectis, or FRENCH CHALK, is found pretty plentifully in Cornwall. Its colour is either white, yellow, or red and white; ſome ſpecimens have the appearance of Caſtile ſoap.

3. SERPENTINE STONE is of different ſhades of green. The ſtructure of this ſtone is fibrous, and it might therefore be confounded with another earthy matter, called aſbeſtos, if its fibres did not adhere ſo cloſely together, as to eſcape obſervation, when the ſtone is cut and poliſhed. Of the ſerpentine ſtone there are many varieties, and it is found ſpotted or ſtreaked with a great diverſity of colours. What is commonly called ſerpentine ſtone, is a true lapis ollaris; but

being variegated like the ſkins of ſome ſerpents, is diſtinguiſhed by another name. Great quantities of this ſtone are found in Italy and Switzerland, where it is often worked into the ſhape of diſhes and other veſſels. It is harder than ſteatites, but not ſo hard as to give fire with ſteel; and leſs ſmooth to the touch, but is ſuſceptible of a good poliſh; it looks like marble, and is often in thin pieces ſemitranſparent. The greener ſorts of this ſtone have been called nephritic; their colour ariſes from manganeſe. But the term lapis nephriticus is commonly applied to jade.

4. Micaceous earths, or TALKS, may be defined earthy or ſtony bodies, the texture and compoſition of which conſiſts of thin flexible particles, diviſible into plates or leaves, having a ſhining ſurface. Theſe plates, by being expoſed to heat, ſeparate into ſmaller ones, but their flexibility is much diminiſhed. By a ſtrong heat they curl or crumple, but it is very difficult to reduce them to perfect fuſion without addition. The plates of mica, when of the pureſt kind, are tranſparent, and there is one variety, the plates of which, from their near reſemblance to glaſs, are called Muſcovy glaſs. Micas, however, are often tinged with a variety of colours, or are more or leſs opake. Sometimes they have a luſtre reſembling that of metallic ſubſtances. Sometimes they are in the form of ſhining powder, like that which is uſed in bronzing figures. This appearance has often impoſed upon miners, who have thought they met with gold and ſilver, whereas

there is never any metal in theſe ſubſtances but iron. They are found alſo mixed with other ſtones, as the granite, which frequently contains a great quantity of talk. Freeſtone alſo contains more or leſs; its horizontal layers have between them a thin ſtratum of talk where the ſtone more eaſily ſeparates. It is alſo found in ſome kinds of ſlate, which, when expoſed to the air, moulder into talky powder. The tranſparent Muſcovy glaſs is uſed for windows, and for thoſe lanthorns which are employed in powder magazines, as this ſubſtance is not ſo liable to break as glaſs, and is unaſſailable by fire. The twiſted, or crumpled mica, which is found at Hardal in Jempland, is there manufactured into kettles and other veſſels, as alſo for hearths of chimnies; and the powder which falls in the working may be mixed with common ſalt for the diſtillation of the muriatic acid. The ſhining appearance of the micaceous earths has obtained them the names of daze, glimmer, or gliſt. Talk differs from other micas in its laminæ or filaments being much tenderer and more brittle, but both have the metallic luſtre.

5. The ASBESTOS, or amianthus, is a foſſil agreeing with talk in having a regular ſtructure, in being flexible, but differing in being compoſed of fibres inſtead of plates. When long expoſed to air, it diſſolves into a ſort of downy matter, which has ſome degree of toughneſs, but the fibres of which connot be unravelled. Cloth and paper have been made of this ſubſtance, which reſiſt the fire. Aſbeſtos,

beſtos, however, though unaſſailable by common fires, has ſubmitted to the power of ſtrong burning mirrors, and has undergone vitrification. The acnients are ſaid to have manufactured cloths of this foſſil, in which they wrapped their dead when they burned them, that the aſhes might be preſerved. Several moderns have ſucceeded in making this cloth; the chief contrivances which are neceſſary are to mix the mineral fibres with a large proportion of flax, and to uſe oil freely; theſe matters are afterwards conſumed by expoſing the cloth to a red heat. Although the cloth of aſbeſtos when ſoiled is reſtored to its whiteneſs by burning, yet it does loſe ſome part of its weight, as has been aſcertained by accurate experiments. The varieties of this curious genus of foſſils are mountain leather or cork; mountain flax, to which the name of amianthus is particularly applied; common or unripe aſbeſtos, and mountain wood. Theſe ſubſtances all conſiſt nearly of the ſame component parts, and differ chiefly in colour, ſolidity, or in the form and direction of their fibres. Some ſpecimens of the amianthus are ſo light as to float in water. When the fibres are parallel, it is called mountain leather; when twiſted, mountain cork.

The mountain cork or leather contains in the hundred from 56 to 62 parts of ſiliceous earth, from 22 to 26 of mild magneſia, from 7 to 14 of mild calcareous earth, 1.7 of clay, and 10.6 of iron. Theſe afford a white ſlag by fuſion. The ſpecimens which are of a yellowiſh *brown* colour are impure, and melt pretty eaſily into a black ſlag. There is alſo a ſpecies of a light green colour, ſomewhat more brittle, and contaminated with iron. This laſt is ſoluble by heat into a ſemitranſparent glaſs.

CHAP. XII.

PONDEROUS EARTHS.

Barytes a ſcarce Mineral; found in two States.—Criſtatum.—Ponderous Spar.—Cawk.—Liver Stone.

BARYTES is but thinly ſcattered in nature. It is found in two ſtates, combined either with the carbonic or vitriolic acids. 1ſt. When united with the former acid it reſembles alum, but is hard and ſtriated, as if compoſed of radiating fibres coming from a center. It is ſometimes of a greeniſh colour; ſometimes jagged, when it is called *criſtatum*, from its reſemblance to a cock's comb. Theſe prominences are found accreted to balls of the ſame ſubſtance.

2. Ponderous earth is more frequently united with vitriolic acid. Theſe ſtones are found of various appearances, pale yellow, blackiſh, with coarſe ſcales, or with fine ſparkling ſcales. They are either tranſparent or opake. The tranſparent PONDEROUS SPAR is uſually in the form of a ſix-ſided very flat priſm, ending in a four-ſided pyramid; but, like all other cryſtals, liable to be varied by the circumſtances attending their formation. The opake ſpecimens, called CAWK by the miners, are of a white,

grey, or fawn-colour; frequently of no regular figure, but often in the peculiar figure of a number of ſmall convex lenſes united together. Theſe varieties are all remarkably heavy, in general exceeding four times the weight of water, and by this circumſtance the preſence of barytes may commonly be diſcovered. The ſtones compoſed of vitriolic acid and barytes may be known by their ſmelling like liver of ſulphur when rubbed. From this property they are called *lapis hepaticus*, and *leberſtein* (liver-ſtone) by the Germans.

CHAP. XIII.

ARGILLACEOUS EARTHS.

General Account of Clays or Argils.—Alum; its Compoſition.—Natural Hiſtory of Alum.—Action of this Subſtance on other Bodies.—Uſes of Alum in the Arts.—Lac Lunæ.—Porcelain Clay.—Manner of making different Kinds of Pottery.—Stone Ware.—Yellow, or Queen's Ware.—China.—Lithomarga.—Terra Lemnia.—Bole.—Zeolite.—Lapis Lazuli.—Tripoli.—Brick Clay.—Slate.

THE argill, or earth of clay, is one of thoſe ſubſtances which abound moſt in nature. There are immenſe ſtrata of clays, and they make a part of every rich ſoil. The idea commonly entertained of clay, is that of a natural ſubſtance, the pureſt kinds of which are firm, and have a ſort of fatneſs or unctuoſity, and which by being rubbed by the finger receive a poliſh. When dry, they imbibe moiſture, ſo that when applied to the tongue it adheres to them. From their attraction for water, they are always found moiſt in a natural ſtate. If more water is added, they form a ductile paſte, which, when thoroughly burnt and dried, becomes hard, ſtony, and impenetrable to water. On the regular contraction which clay undergoes from the application of different degrees of heat, depends the conſtruction of a thermometer for meaſuring intenſe degrees of heat, and invented by Mr. Wedgwood*.

As clays when wrought together become impenetrable to water, they are made uſe of to retain water in ponds, &c. This is the reaſon that when cattle are allowed to tread a clayey ſoil in wet weather, the plants die that grew there; for the clay being previouſly mixed with the water, and being then compreſſed by the feet of the cattle, the ground is rendered too tough for the vegetables to ſpring up through it, eſpecially when the clay thus trodden together is afterwards dried by the heat of the ſun. Clays differ much in conſiſtency. Some melt in the mouth, others are gritty, and get between the teeth. They are white, blue, grey, red, yellow, or black. Some are much leſs viſcid than others. Some reſiſt a very violent heat without undergoing any change; but moſt of them, in very intenſe heat, melt into a vitrified maſs. Some of them effervеſce with acids, others not. All theſe varieties have but one ſpecies of earth for their baſis, and are nothing more than mixtures of pure clay with heterogeneous ſubſtances. Thus we often find ſtrata, which contain a large mixture of ſandy and gritty particles. All clays which are ſandy, are ſo from ſand, or calcareous earth: when mixed with the latter, they effervеſce. The variety of their colour depends on an admixture of iron; though ſometimes of inflammable matter. The clay becoming white in the fire, is the ſureſt ſign of its purity. We can actually extract iron from moſt of theſe clays, eſpecially thoſe which burn to a red colour, which colour is always aſſumed by the calces or ruſt of iron. When they effervеſce with acids, they claſs with marles. Clay, united with vitriolic acid, forms that common and well known ſubſtance called ALUM.

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* See vol. i. p. 96.

The Στυπτηρια of the Greeks, and the alumen of the Romans, was a native ſubſtance, and differed much from the ſalt of which I am now treating. The varieties mentioned by Dioſcorides refer to ſtalactites, which contained very little if any alum, and that completely enveloped by a vitreous matter. The deſcriptions of Pliny are ſtill more difficult to be underſtood, as he had not ſeen the ſubſtance which he deſcribes, but merely tranſcribed from others. The factitious ſalt which is now called alum, was firſt diſcovered in the eaſtern countries, but when, where, or by what means, is unknown. On account of its ſimilar aſtringency, and its uſe in the arts of tanning and dying, the new ſalt has retained the old name.

Among the moſt early works for the preparation of alum, was that of Roccho, a city of Lycia, now called Edeſſa, hence the appellation Roch alum (now commonly miſtaken for rock alum). In the neighbourhood of Conſtantinople, and other parts near Smyrna, were many alum-works. The Italians hired and made uſe of theſe, but about the fifteenth century introduced the art into their own country.

Bartholomew Perdix, or Pernix, a merchant of Genoa, who had often been at Roccho, diſcovered the matrix of alum in the iſland of Iſchia, about the year 1459, and eſtabliſhed a manufactory there; at the ſame time John de Caſtro made the ſame diſcovery at Tolfa, by means of the ilex aquifolium, which he had alſo obſerved to grow in the adjacent mountains of Turkey; and his opinion was confirmed by the taſte of the ſtones. The attempts of the Genoeſe at Viterbium and Volaterre ſucceeded extremely well; inſomuch that an edict of Pope Pius II. prohibited the uſe of oriental alum.

Manufactories were eſtabliſhed in Spain, Germany, England, Sweden, &c. in the courſe of the ſixteenth century.

The proportion of the principles may be aſcertained in the following manner: the water is expelled by a gentle heat; the remaining maſs grows opake, ſwells, foams, and at length grows quiet, ſpongy, and friable; the quantity of earthy baſis is eaſily determined by precipitation with fixed or volatile alkali.

Mr. Pott firſt obſerved that when clay is mixed with vitriolic acid, and boiled a conſiderable time, the ſolution affords alum, though he obtained but little in this way. Margraff found that the vitriolic acid diſſolves one half or more of the pureſt clay; from the ſolution he obtained much alum, but always found it neceſſary to add a certain portion of alkaline ſalt before the alum would appear; and he could never obtain it without adding a greater quantity of vitriolic acid than was neceſſary to compoſe the alum. The other half, which did not diſſolve, he concludes to be a very fine ſand, or an earth of the flinty kind. The ſhorteſt way is to add a ſmall quantity of fixed or volatile alkali to the ſolution, which immediately becomes muddy, the alkali attracting ſome of the ſuperfluous acid, a powder precipitates, conſiſting of the cryſtals of alum.

The alum, however, which is employed in the arts, is not prepared in this way. Nature produces but a very ſmall quantity of actual alum, and this is mixed with heterogeneous matters, or effloreſcences, in various forms, upon ores during calcination, but rarely occurs cryſtallized. In this latter ſtate, it is reported to be found in Egypt, Sardinia, Spain, Bohemia, and other places; it is ſometimes generated in the aluminous ſchiſt of Lapland and Weſt Gothland, by a ſpontaneous decompoſition of the ore; beſides it is found (but rarely) in mineral ſprings. Alum is moſtly prepared from certain foſſils, or ores of alum, as they are called. Theſe ores are generally found in ſtrata, which appear like indurated clays, of a dark black colour, and have a ſulphureous ſmell. When expoſed to the air for ſome time, they grow hot, ſwell, and crumble down into a powder, emit ſulphureous fumes, and ſometimes take fire. Some do not undergo this change merely from expoſure to the air, but muſt be firſt burnt and waſhed, and then expoſed to the air a good while before alum can be obtained. After they have been crumbled down in this manner, they are ſteeped in water; an alkali is then added, and the alum cryſtallizes and ſubſides.

Theſe ores are evidently natural mixtures of clay and ſulphur. By expoſure to air, according to the old ſyſtem of chemiſtry, it was ſuppoſed that the clay acted on the ſulphur in ſuch a manner as to make it part with its phlogiſton, whence they explained the production of heat. This fact, however, is now much better explained, according to the new ſyſtem, by ſuppoſing that the oxygenous gas of the atmoſphere is decompoſed; and while the oxygen is abſorbed by the ſulphur (with which it forms vitriolic acid) the heat is ſet at liberty, and becomes ſenſible.

After a proper quantity of alkali has been added to the ſolution, it is cryſtallized in the common manner, that is by evaporation. The cryſtals are at firſt tolerably diſtinct, but of no conſiderable ſize. A great quantity of them being heaped together until they undergo a watery fuſion, they unite into a maſs, which is called roch alum, and in this form it is expoſed to ſale.

That accurate and attentive obſerver, Biſhop Watſon, in his Chemical Eſſays, relates, that being one day engaged, in evaporating ſomething or other from a ſaucer made of Staffordſhire yellow ware, he was ſurpriſed to ſee a white ſubſtance bubbling through a crack in the ſaucer; upon taſting it, he found it to be a ſalt, and, upon further examination, diſcovered that it was a perfect alum. The fire, he obſerves, was a very hot one, and it was made of coal cinders; the ſaucer was placed on the bar of the grate, and the alum, he conceives, was formed from the ſulphureous acid of the cinders uniting itſelf with the clay, which enters into the compoſition of the yellow ware. He was informed that the vapour which, in ſome places, eſcapes from the coal-pits which are on fire in Staffordſhire, forms an alum whenever it meets with an argillaceous earth. This, he remarks, is conformable to the manner of making alum on the Solfatara, near Naples, where they place little heaps of argillaceous earths or ſtones over the crevices from which the ſulphureous vapour iſſues, in order that they may collect a greater quantity of alum.

This ſalt contains much water, hence it undergoes what chemiſts call the watry fuſion; after this there remains a ſubſtance called burnt alum, which contains the earth and vitriolic acid, with little or no water; this, if the heat is increaſed, does not melt, nor by heat alone can we ſeparate the whole of the acid, though ſome of it riſes; but the addition of any inflammable matter diſpoſes it to riſe in fumes, which are very ſulphureous. One hundred parts of cryſtallized alum contain thirty-eight of vitriolic acid, eighteen of clay, and forty-four of water.

The ſenſible qualities of alum ſhew it to be the oppoſite to borax, which is compoſed of the fixed alkali and a very weak acid; on the contrary, alum is the ſtrongeſt acid, combined with an earth which attracts it very weakly; ſo that the qualities of the acid are very little altered, for if we apply a ſolution of alum to the infuſion of litmus, it changes it to a red. The ſolution has alſo a manifeſt acidity, combined with another taſte which approaches to ſweetneſs. If an alkali is added, the earth is immediately precipitated, and this effect is not only produced by the fixed and volatile alkalies, but by magneſia and calcareous earth. Alum is often obtained from the liquor of the compound of iron and vitriolic acid.

The earth of alum will combine in exceſs to the ſalt when already formed. M. Beaumé boiled a ſolution of alum with the earth precipitated from another portion of alum, by means of fixed alkali; the earth was diſſolved with efferveſcence, the filtrated ſolution had no longer the taſte of alum, but that of a hard water, did not redden the tincture of turnſole, but converted ſyrup of voilets to a green. By ſpontaneous evaporation it afforded cryſtals, ſcaly and ſoft to the touch like mica; M. Baumé compares them to ſelenite. It is not eaſy to compoſe alum by adding vitriolic acid to this ſaturated ſalt, the mixture becoming acid, but not ſtyptic. However, after ſpontaneous evaporation for three months, the ſolution afforded cryſtals of alum mixed with ſome micaceous ſcales, ſimilar to thoſe afforded by alum ſaturated with its earth.

Alum, heated with combuſtible matters, forms a ſubſtance which takes fire on expoſure to air, and is called the pyrophorus of Homberg. This chemiſt, who publiſhed an account of the pyrophorus, in the year 1711, made experiments on human excrement, for the purpoſe of obtaining a colourleſs oil poſſeſſing the property of fixing mercury into fine ſilver: the inquiry produced many diſcoveries; the reſidue of this animal ſubſtance, diſtilled with alum, took fire on expoſure to the air. Homberg repeated this experiment a number of times, and always with ſucceſs. Lemery the younger, in the years 1714 and 1715, publiſhed two memoirs, in which he affirms, that pyrophorus may be made with a great number of vegetable and animal ſubſtances heated with alum. But he did not ſucceed in his attempts to form it with ſome other vitriolic ſalts. Theſe two chemiſts, who ſuppoſed alum to be a combination of the vitriolic acid and calcareous earth, imagined that the latter being converted into lime attracted the humidity of the air, and produced a degree of heat ſufficient to ſet fire to the ſulphur formed by the vitriolic acid and inflammable ſubſtances.

Alum is one of the moſt uſeful ſalts in the arts. It is added to tallow to make candles hard. Wood ſufficiently ſoaked in alum does not eaſily take fire: the ſame is true of paper impregnated with it, which for that reaſon is very proper to keep gun-powder, as it alſo excludes the moiſture of the air. This paper is alſo uſeful in whitening ſilver, and in ſilvering braſs without heat. Alum is uſeful added to milk which does not eaſily ſeparate its butter.

It is particularly uſeful in dying, in preparing the matters to be dyed; for by cleanſing and opening the pores upon the ſurface by a gentle corroſion, it both renders the ſubſtance fit for receiving the colouring particles (by which the alum is generally decompoſed) and at the ſame time makes the colour fixed. It conſtitutes the baſis of crayons, which generally conſiſt of the earth of alum, finely powdered and tinged for that purpoſe, with different colouring matters.

The argillaceous foſſils are referred to the following heads:

I. ARGILLA AERATA, to which the fanciful name of lac lunæ has been applied. This was ſuppoſed to be a particular ſpecies of calcareous earth, till M. Screber found that it was a combination of argill with the carbonic acid. It efferveſces with acids, and contains a very ſmall proportion of calcareous earth, and ſometimes of gypſum. It is generally found in ſmall cakes of the hardneſs of chalk, like which it marks white. Its colour is ſnow white, and when examined by the microſcope it is found to conſiſt of ſmall tranſparent cryſtals. It efferveſces with acids.

II. PORCELAIN CLAY, argilla apyra, the *kaolin* of the Chineſe. This is very refractory, and is with great difficulty brought into perfect fuſion. After it has been ſubmitted to the action of heat, it is of a ſolid texture, and is ſo hard as to ſtrike fire with ſteel. It is found of an excellent quality in Japan, and likewiſe in different parts of Europe. In Sweden it is met with in coal-pits, between the ſtrata of coal. Common pipe clay belongs to this diviſion, and differs from porcelain clay only in being leſs pure, which prevents its burning to a good colour.

The eſſential ingredient in all kinds of pottery is clay or argillaceous earth, becauſe theſe earths are capable of being kneaded, and eaſily receiving any form, and of acquiring much ſolidity and hardneſs by expoſure to fire. Pottery is, in general, covered with a glazing, or is made to undergo a vitrification at the ſurface, without which it would be pervious to fluids. Ordinary pottery is glazed with glaſs of lead mixed with metallic calces, or with fuſible metallic earths. A fine kind of pottery is made of white clays, or ſuch as whiten in the fire; the ſurface of which is vitrified by throwing into the furnace, when the ware is ſufficiently baked, ſome common ſalt and ſaltpetre. The Engliſh ſtone ware is compoſed of tobacco-pipe-clay and ground flints. The uſe of the flints is to give ſtrength to the ware, ſo that it may preſerve its form during the baking. In making this ſtone-ware great pains are taken to employ only the finer particles of the clay and flint. With this view the clay is much beaten in water, by which the finer parts being mixed with the fluid are ſuſpended, while the coarſer ſink to the bottom of the veſſel. The thick liquid, conſiſting of water and the finer particles of the clay, is farther purified by paſſing it through hair and lawn ſieves of different degrees of fineneſs. After this the liquid is mixed, in various proportions for different wares, with another liquor, of about the ſame denſity, and conſiſting of flints calcined, ground, and ſuſpended in water. The mixture is then dried in a kiln, and afterwards, being beaten to a proper temper, it becomes fit for being formed at the wheel into diſhes, plates, bowls, &c. When the ware has been expoſed to heat for about forty-eight hours, it is glazed by means of common ſalt. This is thrown into the furnance through holes in the upper part of it, and being converted into a thick vapour by the heat, is applied to the ſurface of the heated ware, and cauſes it to vitrify. This curious method of glazing earthen ware was introduced into England by two Dutchmen, near a century ago. It appears to be produced by a combination of the alkali of the ſalt with the ſiliceous earth of the pottery. The yellow or queen's ware is made of the ſame materials as the flint ware, but in different proportions. The glazing is alſo different; it is made by mixing together in water, till it becomes as thick as cream, one hundred and twelve pounds of ground white lead, twenty-four pounds of ground flint, and ſix pounds of ground flint glaſs. The ware, before it is glazed, is baked in the fire, by which it acquires the property of ſtrongly imbibing moiſture; it is then dipped in this compoſition, and ſuddenly taken out. It is afterwards expoſed a ſecond time to the fire, by which means the glaze it has imbibed is melted, and a thin glaſſy coat is formed upon its ſurface, which is more or leſs yellow, according as a greater or leſs proportion of lead has been uſed. Porcelain, or china, is a ſemivitrified earthen ware of an intermediate nature between common wares and glaſs. The firſt ſpecimens of this beautiful manufacture came from China and Japan. Chineſe porcelain is ſaid to be compoſed of two ingredients, one of which is a hard ſtone or rock called *petuntſe*, which they carefully grind to a very fine powder; and the other, called by them *kaolin*, is a white earthy ſubſtance, which they mix intimately with the ground petuntſe. Reaumur examined both theſe matters; and having expoſed them ſeparately to a violent fire, he diſcovered that the petuntſe had fuſed without addition, but that the kaolin had given no ſign of fuſibility;

from which it appeared that the former was of a flinty nature, and the latter argillaceous. He afterwards mixed theſe matters, and formed cakes of them, which, by being baked, were converted into porcelain ſimilar to that of China. Macquer thinks that the firſt European porcelains were made in Saxony and in France; and afterwards in England, Germany, and Italy. Manufactories have ſince been eſtaliſhed in almoſt all the countries of Europe, in many of which porcelain is made very little if at all inferior to the Chineſe.

III. Lithomarga, or STONE-MARROW, when dry, feels as ſlippery as ſoap, but is not wholly diffuſible in water. When mixed with water, it falls in pieces, ſo as to aſſume the appearance of curds. In the fire it melts into a frothy ſlag. In the maſs it breaks into irregular ſcaly pieces. This is the fuller's earth uſed in the dreſſing of cloths. To this ſpecies alſo belongs the terra lemnia; this is of a browniſh colour and ſhining texture, and falls to pieces in water with a crackling noiſe. The terra lemnia is ſo called from the iſland of Lemnos, now Statimane, in the Ægean ſea, whence it is procured. It is likewiſe called the Turkiſh earth, on account of its being impreſſed with the ſeal of the grand ſignior.

IV. BOLE is a fine and denſe clay of various colours, containing a large quantity of iron. It is not eaſily ſoftened in water when indurated, as the porcelain and common clays, but either falls to pieces in the form of fine grains, or repels the water, and cannot be made ductile. In the fire it grows black, and is then attracted by the loadſtone. The ſoft boles are of various colours, as red, yellow, green, grey, and blueiſh grey. The red kind is that uſed in medicine, under the name of Armenian bole; an indurated kind of which affords the material for red pencils. An indurated bole is frequently found in coal-pits, between the ſeams of coal, and is called coal-ſlate. It is met with frequently in pieces like nuts of various ſizes; which when broken exhibit impreſſions of plants, as the nodules of copper-ſlate from Ilmenaus contain repreſentations of fiſh. A ſpecies of bole is found with ſcaly particles, the *hornblende* of the Swedes. It is diſtinguiſhed from mica, by the ſcales being leſs ſhining, thicker, and rectangular. It is frequently mixed with pyrites; it is of two kinds, black and greeniſh. The former, when rubbed fine, affords a green powder, and is either of a lamellated or granular texture. The greeniſh kind is of a granular texture, or ſtriated.

V. ZEOLITE is in general of a cryſtalline form, compoſed of imperfect pyramids turned towards a common center. Their form is ſometimes globular, but ſeldom priſmatic. The lapis lazuli belongs to the zeolites. Theſe foſſils are harder than fluors, but may be ſcratched by ſteel. The ſiliceous earth predominates much in them. The lapis lazuli contains ſilver and iron, which gives the blue colour. Zeolite melts *per ſe* with ebullition into a white frothy ſlag, which in the moment of fuſion affords a phoſphoric light. The lapis lazuli firſt becomes brown when melted, and then produces a clear glaſs with blue clouds. By ſcorification with lead, one hundred weight of it has afforded two ounces of ſilver.

VI. Tripoli ſeems to be of a volcanic origin. It is an earth conſiſting of very fine particles, and is known by its quality of rubbing or wearing hard bodies, which gives them a poliſh. Other fine clays, however, have the ſame property when a little burnt. The tripoli grows ſomewhat harder in the fire, and is fuſed with great difficulty. When crude it imbibes water, but is not ſoluble in it. It taſtes like chalk, and is rough or ſandy between the teeth, though no ſand can be ſeparated from it. That which has been juſt deſcribed is of a yellow colour, and is ſold by druggiſts. This kind of tripoli has been lately diſcovered in Scotland. Another variety, called the rotten-ſtone, is found in Derbyſhire. It is in common uſe in England for all ſorts of finer grinding and poliſhing, and is alſo ſometimes uſed by lapidaries for cutting of ſtones.

VII. Common or brick clay is found of various colours, as red, pale red, grey, and blue. It acquires a red colour, more or leſs deep, in the fire, and melts pretty eaſily into a greeniſh glaſs. It conſiſts of a mixture of pure clay, ſiliceous and martial (or iron) earths, containing alſo a ſmall quantity of vitriolic acid. The clay is alſo found mixed with calcareous earth, when it conſtitutes marle. It is alſo found in an indurated ſtate, either pure or mixed with inflammable ſubſtances, and vitriolic acid, in which caſe it forms the ores of alum.

VIII. Argillaceous foſſile ſtones, to which the denomination of SCHISTI properly belongs. The moſt remarkable ſtones comprehended under this diviſion are the bluiſh purple ſchiſtus, or common roof ſlate; the dark blue ſchiſtus, or writing ſlate; the pyritaceous ſchiſtus; the bituminous ſchiſtus; the argillaceous grit, which is alſo called ſand-ſtone, and free-ſtone; the killas; the flag-ſtone, and the toad-ſtone.

The method of ſplitting the ſlate, uſed for the roofing of houſes, is the following: They expoſe it in blocks to be well wetted and ſoaked by the rain; when the froſt comes upon it afterwards, it rarifies the water, and cracks and opens all the joints of the ſtone, ſo that when the froſt has completed its work it lies in looſe flakes or ſhivers. Thus the elements perform with eaſe what no manual art could have eaſily accompliſhed.

CHAP. XIV.

SILICEOUS EARTHS.

General Arrangement of Flinty Subſtances.—Gems.—Diamond.—Ruby.—Sapphire.—Topaz.—Emerald.—Hyacinth.—Amethyſt.—Garnet.—Tourmalin.—Opal.—Compoſition aud Properties of precious Stones.—Quartz.—Rock Cryſtals.—Pebbles.—Flints.—Lapis Nephriticus.—Cat's-Eye.—Hydrophanes.—Explanation of the Phenomena of the Hydrophanous Stone.—Moon-Stone.—Chalcedony.—Onyx.—Carnelion.—Sardonyx.—Agate.—Common Flint.—Chert.—Sand and Gravel.—Jaſper.—Feldt Spar.—Labrador Stone.—Schirl and Whetſtone.—Art of making Glaſs.—Prince Rupert's Drop and Philoſophical Phial.—Curious Phenomenon.

THESE earths are chiefly diſtinguiſhed by their hardneſs, by which they ſtrike fire with ſteel, and their property of forming good glaſs with alkali. They may be divided into, 1, Gems, or precious ſtones; 2, Quartz; 3, Flints; 4, Jaſpers; 5, Feldt-ſpars.

1. GEMS.—The diamond is the hardeſt of all bodies. Its ſpecific gravity is 3,445, hence it refracts the rays of light very powerfully; but it poſſeſſes this power even in a much greater degree than might be ſuppoſed from its denſity, and hence proceeds its ſingular brilliancy. The diamond, properly ſo called, is colourleſs; but it alſo retains this name when it is ſlightly tinged either with red or yellow. It is therefore not the colour of the ſtone, but its

hardneſs and luſtre, which obtain it the denomination of a diamond.

Diamonds are found in the Eaſt Indies, particularly in the kingdoms of Golconda and Viſapour: they likewiſe come from the Braſils; but theſe laſt appear to be of an inferior quality, and are known in commerce by the name of Portugueſe diamonds.

Diamonds are uſually found in an ochreous yellow earth, under rocks of grit-ſtone and quartz; they are likewiſe found detached, in torrents which have carried them from their beds. Diamonds are ſeldom found above a certain ſize. The ſovereigns of India reſerve the largeſt, in order that the price of this article may not fall. Diamonds have no brilliancy when dug out of the earth, but are covered with an earthy cruſt, which incloſes a ſecond cruſt, of the nature of calcareous ſpar, according to M. Romé de Liſle. Bright diamonds are occaſionally found in waters.

Diamonds very often have no regular form, but are flat, or worn round. Sometimes they are regularly cryſtallized in octahedrons, formed by two quadrangular pyramids, united at their baſis; they are likewiſe found with twelve, twenty-four, and forty-eight faces.

Diamonds appear to be compoſed of laminæ, laid upon each other; and they are eaſily divided, by ſtriking them in the direction of theſe laminæ with a good ſteel inſtrument. There are, however, ſome diamonds which do not appear to be formed of diſtinct laminæ, but of twiſted fibres, like thoſe of knots in wood. Theſe laſt are exceedingly hard, and cannot be wrought; lapidaries call them diamonds of nature.

Diamonds are ſhaped by firſt cleaving them in the direction of their lamellæ, and then rubbing them with other diamonds. They are then poliſhed by an horizontal ſteel wheel, duſted with their own powder mixed with olive oil.

2. The ruby has been confounded with the diamond, on account of its hardneſs and luſtre, but ſome late experiments ſhew that it is eſſentially different. According to Cronſtadt, there are four principal kinds of rubies:—1. The ruby of a deep colour inclining to purple. 2. The ſpinell ruby, of a ponceau red, that is, of a bright corn-poppy-flower colour. 3. The balaſs-ruby, pale red inclining to violet. 4. The rubicell, of a reddiſh colour.

3. The ſapphire is tranſparent, and of a blue colour, and is ſaid to be next to the diamond in hardneſs. They are ſometimes of a milky appearance.

4. The topaz is chiefly of different ſhades of yellow, but is ſometimes greeniſh. When of a ſea-green colour it is called aqua-marine; when more green, the beryl; when yellowiſh green, the chryſolite.

5. Emerald, the chief colour of which is green, is the ſofteſt of the precious ſtones, and when heated is phoſphoreſcent like the fluors.

6. The jacinth or hyacinth, is of a fine reddiſh yellow colour, and ſometimes brown; they are formed in priſms, pointed at both ends.

7. The amethyſt is a gem of a violet colour, or great brilliancy, and as hard as the beſt kinds of rubies and ſapphires, from which it only differs in its colour. This is called the oriental amethyſt, and is very rare; when it approaches to the purple, or roſe colour, it is more eſteemed than when it inclines to the blue.

The amethyſts called occidental, are of the ſame nature as rock cryſtals, and have the ſame gradations of colour. Cryſtals within the geodes, or hollow agate-balls, are very often found of an amethyſt colour, and ſome are very fine.

8. The garnet, when tranſparent and of a fine colour, is reckoned among the gems; but it varies more than any, both with reſpect to its form and colour, ſome being of a deep and dark red, ſome yellow and purple, and ſome brown, blackiſh, and quite opake. The regular ſhape of the garnet is the dodecagon, with rhomboidal faces, and its chief variation is, the double eight-ſided pyramid, terminating by four faces on each end. In general their luſtre is leſs than that of other gems, as well as their hardneſs, which yields to the file, though they ſometimes ſtrike fire with ſteel. Their colour proceeds from the iron which they contain; and, according to M. de Sauſſure, even the fineſt oriental garnets attract the magnetic needle at a ſmall diſtance. The Syrian garnet is the fineſt, and moſt eſteemed: it is of a fine red, inclining to a purple colour, very diaphanous, but leſs brilliant than the oriental amethyſt.

9. The tourmalin has lately been brought much

into notice by its remarkable property of becoming electrical, in conſequence of the ſimple application of heat. If it is immerſed in hot water, in which proceſs no friction can be ſuppoſed to happen, after it is removed it gives ſigns of contrary electricity at the two oppoſite ends of its priſmatic form.

The oriental tourmalins are found in the iſland of Ceylon: they are tranſparent, of a dark brown yellow. From Braſil they are for the moſt part green; but there are alſo ſome red, blue, and yellow. From Tyrol they are obtained of ſo dark a green, as to appear opake. They are alſo found in the mountains of Old Caſtile in Spain.

10. The opal is a moſt beautiful ſtone, from the changeable appearance of its colours by refraction and reflection. There are two kinds; one of which, the opal of Nonnius, appears olive-coloured by reflection, and then appears to be opake; but when held againſt the light, it is found to be tranſparent, and then appears of a fine red colour. The white opal, of a glaſs-like complexion, throws out green, yellow, purple, and bluiſh rays; but it is of a reddiſh, or rather flame-colour, when held againſt the light.

The precious ſtones are chiefly compoſed of the argillaceous and ſiliceous earths; of which the former predominates. The diamond is alſo thought to contain a peculiar earth, of different properties from thoſe of any of the five earths above deſcribed.

On diſſolving the very ſubtle powder of the gems in a double weight of vitriolic acid highly concentrated, the reſiduum, after evaporation, being waſhed with warm water, yields a metallic colouring ſubſtance, and a ſmall portion of lime. The metallic part, precipitated by what was in the old chemical nomenclature called a phlogiſticated alkaline lixivium, yields a beautiful Pruſſian blue; hence we conclude that the red colour of the ruby, as well as the blue of the ſapphire, the yellow of the topaz, the tawny of the hyacinth, and the green of the emerald, are to be attributed to iron*.

Bergman obtained by analyſis, from one hundred parts of the following precious ſtones:

	Clay.	Flint.	Lime.	Iron.
Emerald,	— 60	— 24	— 8	— 6
Sapphire,	— 58	— 35	— 5	— 2
Topaz,	— 46	— 39	— 8	— 6
Hyacinth,	— 40	— 25	— 20	— 13
Ruby,	— 40	— 39	— 9	— 10

From the above it may be collected, that the gems agree in this reſpect, that they all conſiſt of the ſame principles; and that of theſe the argillaceous earth forms the greateſt part, then the ſiliceous, next the calcareous, and leaſt of all the iron †. The gems, except the emerald and hyacinth, reſiſt the moſt intenſe fire; yet we know that the ruby has been ſoftened in the focus of a burning mirror *.

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* Bergman's Diſſertations, p. 15.

† Chemical Eſſays, Diſſ. 15.

Theſe ſtones all aſſume different forms of cryſtallization, and as this affects the arrangement of their minute parts, it doubtleſs is not without effect on their external appearance. Their value depends on their hardneſs and tranſparency. The degrees of hardneſs are—1. diamond; 2, ruby; 3, ſapphire; 4, topaz; 5, hyacinth; 6, emerald.

The garnet differs from all the above, in the ſiliceous earth being more prevalent than the argillaceous.

II. Quartz has leſs tranſparency and hardneſs than the precious ſtones. The fracture of quartzoſe ſtones is vitreous, or like glaſs, and they ſtrike fire with ſteel. Heat cauſes them to loſe their hardneſs and tranſparency, and reduces them to a white opake earth. They are generally cracked throughout, and break irregularly, and into ſharp fragments. Melted with alkali they give a more ſolid and fixed glaſs than any others of the ſiliceous order. When there is no interruption to their natural accretion, their ſubſtance always cryſtallizes into hexagonal priſms, pointed at one or both ends. Theſe occur in clefts, fiſſures, and ſmall veins in rocks. Quartzoſe ſtones very often contain metals.

No very remarkable ſtones belong to this genus. The varieties are Fat quartz, which is very gloſſy; it is either colourleſs, or is tinged with white, blue,

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* Chemical Eſſays, Diſſ. 15.

or violet. Dry quartz, tranſparent, white, or pale green. Sparry quartz, pale yellow, or pale blue. Cryſtallized quartz is either opake or tranſparent: the tranſparent and dark-brown kind is called ſmoky-topaz; the yellow, blue, green, and red, falſe gems; and the colourleſs, rock cryſtals; when milky, milk-cryſtals, and pebbles. Quartz is alſo found combined with iron and copper; with the former it conſtitutes a black calx, with the latter a red calx.

III. Flints are more uniformly ſolid, and not ſo much cracked in the maſs, as quartz; and are more pellucid than jaſper. They are better for making glaſs than the jaſper, but not ſo good as quartz, and ſeem in moſt reſpects to be of an intermediate nature between theſe ſtones. Flint often ſhews evident marks of having been in a ſoft and tough ſtate, like glue or jelly.

The ſeveral varieties of flints have obtained more diſtinct names, from the variety of their colours, than from any real difference in their ſubſtance; but theſe are ſtill proper to be retained, as the only names by which jewellers and others are uſed to diſtinguiſh them.

1. Jade, lapis nephriticus. This ſtone feels unctuous to the touch, but is ſo hard as to ſtrike fire with ſteel, and is alſo ſemipellucid. Theſe latter circumſtances ſufficiently denote its flinty nature; though its unctuoſity has induced ſome mineralogiſts to think that it ought rather to be referred to the argillaceous or magneſian orders. It is not

hardened by the heat of the furnace, but it melts by the ſolar heat, in the focus of a burning mirror, into a green glaſs. That called by the name of circumciſion-ſtone, which comes from the Amazon river, melts more eaſily by the concentrated rays of the ſun into a brown opake glaſs. The colour of theſe ſtones is either milky, or different ſhades of green. Thoſe of a grey, olive, or yellowiſh colour, are the vulgar lapis nephriticus; which name they have obtained, from a ſuppoſed property of curing nephritic pains, when applied externally to the loins. Their ſemipellucid appearance, hardneſs, and ſpecific gravity, are characters by which the lapis nephriticus may be diſtinguiſhed from other ſtones.

2. The cat's eye is a very ſcarce ſtone. It is opake, and reflects green and yellow rays, in a manner ſomewhat ſimilar to the eye of the animal from which its name is derived. It is found in Siberia.

3. The Hydrophanes, or oculus mundi. The character which diſtinguiſhes this from all other ſtones is its property of becoming tranſparent in conſequence of being immerſed in water. This happens from its imbibing that fluid, as it becomes again opake by being dried.

This circumſtance may be illuſtrated by a compariſon with ſome other natural phenomena. The appearance of clouds ſerves to ſhew that particles of water, copiouſly mixed with thoſe of air, prevent the tranſmiſſion of light, and render the maſs more or leſs opake, although the particles of each, ſeparately taken, are pellucid. The cauſe of this is to be ſought for in the difference of the refracting power; for, by means of that, the rays are turned from their original courſe at every particle, a circumſtance which is very injurious to tranſparency. A common experiment will ſtill more clearly elucidate this point. The moſt tranſparent glaſs, when reduced to powder, becomes opake, becauſe the air which now occupies the interſtices reflects the light much more copiouſly than the particles of glaſs. But upon pouring on water, which diſplaces the air, and which differs leſs from the glaſs in its refracting power, a certain degree of tranſparency is reſtored. On this principle depends the nature of the hydrophanous ſtone, which is opake when dry, but gradually acquires tranſparency by lying in water. This ſtone agrees nearly in ſpecific gravity with water, at leaſt is not more diſtant from it than glaſs. Its particles are tranſparent, but it is uniformly perforated by inviſible foramina, ſo that the air and water are admitted, but not readily. When dry, therefore, on account of the great difference of the mediums between the particles of the ſtone and thoſe of the air, it is opake; but when the water is gradually imbibed, it grows by degrees pellucid, beginning at the ſurface, and proceeding towards the centre. That the hydrophanes abſorbs moiſture and emits air, which is a fluid of much leſs denſity, appears from the weight it acquires, and the ſmall bubbles which cover its ſurface during the time it is acquiring it tranſparency.

4. Moon-ſtone, or rainbow-ſtone, reflects light of pearl and carnation colours. Its fracture is foliated, and its colour pale blue and milky.

5. Chalcedony, or white agate.—This ſtone is uſually cut with a convex ſurface, and receives a good poliſh. Its degree of hardneſs is intermediate, between that of the onyx and the true agate. It is ſemitranſparent, and its colour is uſually very ſimilar to that of milk diluted with water.

6. The onyx is the hardeſt of flints. Its uſual colour is that of the human nails. It is either marked with white lines only, or with black and white together. Heat deprives it of colour, and, if ſuddenly applied, cracks it.

7. The carnelion derivesits name from its reſemblance to the colour of fleſh. It is either quite red or of different ſhades of red, with brown and yellow.

8. The ſardonyx is a mixture of the chalcedony and carnelion, ſometimes diſpoſed in ſtrata, and ſometimes confuſedly blended and mixed together. Its colours are therefore a mixture of white and red, ſometimes in ſtripes, ſometimes irregularly notched.

9. Agate. This name is given to flints that are variegated with different colours promiſcuouſly blended together, and they are eſteemed in proportion to the mixture and perfection of their colours.

10. Common flint or pebble, is in reality of the ſame nature with agate, but wanting the beautiful and various colours of the ſubſtances that bear that

name. Chalk and white lime-ſtone are uſually the matrices of flints, in which they are imbedded in the form of nodules, conſiſting of nuclei involved in a cruſt.

II. Chert is leſs hard and tranſparent than the common flint. It is not in general found in looſe and ſingle irregular nodules, but forms veins in rocks. Cherts are found of a fleſh-colour, white, pale yellow, and greeniſh, and ſeem to be of an intermediate nature between the flints and jaſpers.

Sand and gravel may be conſidered as flinty matters, torn away from the rocks in which they originally exiſted, and afterwards worn and ſmoothed by the attrition occaſioned by the motion of water. Sand and gravel, however, conſiſt of all the variety of ſtony matters which exiſted in the maſſes from which they proceeded, and are therefore found of many different colours and properties.

IV. The name of JASPERS is given to all the opake ſiliceous ſtones, which in their texture reſemble dried clay. The principal circumſtance, beſides their appearance, which diſtinguiſhes them from the other ſiliceous orders, is their more eaſily melting in the fire. They in general contain much iron. They are very hard, and admit a good poliſh; and they are variegated with different colours. They are ſeldom ranged in ſtrata, but form conſiderable maſſes and veins in rocks. They are alſo found in ſmall round maſſes. The principal ſpecies of jaſpers are the following—the white, grey, yellow, red, brown, green, veined, ſpotted, flowered, and green with red points, or blood-ſtone. Toys, and more eſpecially cups and ſaucers, are made of jaſper. Many antique ſculptures are in ſtones of this nature.

V. The moſt common kind of FELDT-SPAR is formed of rhombic laminæ, and has therefore obtained the name of rhombic quartz. It gives fire with ſteel, whence it has been called ſpathum ſcintillans. It is harder than the ſchiſti, and is fuſible. It is found in looſe maſſes, two inches long, or mixed with ſand, clay, &c. or bedded in granite. It is uſed in making china at Dreſden. Its colours are white, red, brown, pale yellow, or greeniſh.

The Labrador-ſtone is generally claſſed with the feldt-ſpars. It admits of a very fine poliſh, and when in that ſtate reflects a variety of beautiful colours. The ſtone itſelf is of different ſhades of grey.

VI. SHIRL or COCKLE, of different ſhades of green; and the various ſpecies of whetſtones, are alſo commonly referred to the ſiliceous order, though the latter are generally in ſome meaſure compound.

The uſes of the flinty ſubſtances are various, and have been partly intimated; but there is one art, in which their uſe is too conſpicuous to be paſſed over in ſilence.

The art of making glaſs depends on the fuſion of earthy ſubſtances, of which the flinty earth is the beſt, and for that reaſon is called vitrifiable. But as earths cannot eaſily be fuſed without mixture, it is neceſſary to add certain ſubſtances which may promote the vitrification. In the making of ordinary glaſs, two parts of ſand, or other ſiliceous matter,

ter, are mixed with about one of fixed alkali. If the glaſs is not required to be tranſparent, impure alkali, not freed from the aſhes, is employed; but in making the finer and moſt tranſparent kinds of glaſs, care is taken to purify both the earth and the alkali. One of the chief points to be obſerved in the making of glaſs is to heat the mixture gradually, ſo that the elaſtic fluids may eſcape before the materials cohere, as the ingredients are otherwiſe apt to be ſo ſwelled by the diſengagement of air as to be loſt by flowing over the ſides of the veſſel in which they are heated. In order to prevent this, due proportions of ſand and alkali are mixed together, and expoſed, during a conſiderable time, to a red heat, not intenſe enough to melt them. By this calcination the inflammable matters, which would have impaired the colour of the glaſs, are conſumed, and the air expelled. This firſt mixture of the materials of glaſs, after being treated in this manner, is called the *fritt*.

The due degree of heat is an eſſential point in making of glaſs: it ought not only to be very ſtrong, but alſo maintained during a long time. In great manufactories the glaſs is kept fuſed during ten or twelve hours before it is taken out of the pots. The ingredients are thus more completely melted, and more thoroughly mixed, and the appearance of threads or veins is in ſome meaſure prevented, which proceed from the different denſity of different portions of the glaſs, and which therefore act differently on the rays of light. The imperfections of glaſſes are moſt ſenſibly felt in the conſtruction of optical inſtruments.

Good glaſs, although kept in fuſion for a long time in a great heat, is never perfectly liquid. It is always ſomewhat thick, and when taken out may be drawn into fine threads. The great ductility and flexibility of red hot glaſs fits it for being reduced into any form. In general the glaſs is taken out of the pots in which it is fuſed by means of an iron tube. When a ſufficient quantity of the glaſs is collected at the extremity of the tube, the workman begins to blow thro' it, and thus inflates the glaſs. He occaſionally rolls it, in order to form it into a cylinder, a cone, &c. and if it becomes too cold, he heats it by holding it before the mouth of the furnace. Glaſs, in its tough ſtate, may be cut with ſhears, bended with pincers, preſſed into moulds, and wrought, in a variety of methods dependent on theſe properties, into the vaſt variety of forms which it is made to aſſume. Glaſs veſſels, as ſoon as made, are carried to an oven, in which they are gradually cooled; for without this proceſs, which is called *annealing*, they would either break in the cooling, or be liable afterwards to be broken by the ſlighteſt force.

The principal defects of glaſs are colours, veins, and bubbles. The colours which generally injure the common alkaline glaſs are ſhades of green, blue, and olive. Theſe are moſt effectually removed by the addition of a ſmall quantity of mangeneſe. The cauſe of the veins has been already explained, and that of the bubbles depends on the imperfect expulſion of air.

The addition of calx of lead to glaſs renders it much more denſe, and leſs liable to be broken. Artificial gems are only the beſt kinds of glaſs, coloured with different metals; but the modes of applying the ſeveral metals to this uſe will be mentioned when treating of them.

There are two toys made of unannealed glaſs, which, though commonly uſed for the amuſement of children, exhibit phenomena which juſtly intereſt the curioſity of the philoſopher. When a drop of melted glaſs is ſuffered to fall into water, it aſſumes an oval form, with a tail or neck reſembling the retort of a chemiſt. This is called Prince Rupert's drop, and poſſeſſes the ſingular property, that if the ſmalleſt portion is broken off, the whole drop flies into powder with a kind of exploſion, and a conſiderable ſhock is communicated to the hand that graſps it*. The other is called the philoſophical phial, which is a ſmall cylindrical veſſel of glaſs, open at the upper end, and rounded at the bottom. It is generally made of glaſs ſo thick that it will bear a ſmart blow againſt a hard body without breaking, but if a ſmall pebble or piece of flint is let fall into it, it immediately cracks and flies in pieces. This veſſel is formed upon ſimilar principles with Prince Rupert's drop, it conſiſts of glaſs ſuddenly cooled, and, I ſuſpect, by immerſion in water.

* Honour is like that glaſſy bubble,
That gives philoſophers ſuch trouble;
The one part crack'd, the whole will fly,
And wits are crack'd to find out why.
HUDIBRAS.

Various explanations have been offered of theſe facts. The moſt generally received is founded on the aſſumption that the dimenſions of bodies which are ſuddenly cooled remain larger than if the cooling had been more gradual. The dimenſions, therefore, of the ſmooth external ſurface of theſe glaſſes, which are ſuddenly cooled, are ſuppoſed to be larger than is adapted to the accurate envelopement of the internal part, which is neceſſarily cooled in a more gradual manner; if, therefore, by a crack or raſure, a ſolution of the continuity takes place in the external ſurface, the ſudden action of the parts which remained in a ſtate of tenſion, to recover that of perfect coheſion, is ſuppoſed to effect the deſtruction of the maſs.

This explanation I confeſs has not appeared to me ſatisfactory, and I have been inclined to ſuſpect that the phenomenon ariſes either from a quantity of air being included in the ſubſtance of the glaſs, which ruſhes ſuddenly out, on the ſurface which includes it being broken; or that by the ſudden cooling the pores of the glaſs are ſealed up by the fine ſmooth ſurface, and contain little or no air, ſo that on the continuity of that ſurface being interrupted, the air ſuddenly ruſhing into all the pores of the glaſs may effect its diſſolution. That the whole effect depends on deſtroying the continuity of the ſurface, I have ſufficiently proved; for unleſs the flint or pebble which is let fall into the philoſophical phial is large and angular enough to ſcratch the ſurface of the glaſs, it will not break. To aſcertain whether the fracture of theſe toys depends or not upon the air, a few experiments might be made on Prince Rupert's drops in a vacuum; when, if it proceeds from air included in the drop, the exploſion will be more violent, or the drop would, perhaps, ſpontaneouſly burſt; and if from the contrary cauſe, it will not break at all in vacuo.

I know not whether I am correct in introducing in this place a kind of mineral ſubſtance called *ſlickenſides*, which is mentioned by Mr. Whitehurſt *, as I am not even certain that it belongs to the ſiliceous genus, but the ſimilarity in the phenomena which it exhibits to thoſe of the Rupert's drop and the philoſophic phial muſt be my apology. It may be a volcanic production, and may have undergone a ſudden cooling, from ſome accidental cauſe ſimilar to that of the glaſs of which I have been treating.

This ſtone has the appearance of black marble, and breaks where the exploſion happens with a poliſhed ſurface, not truly plane, but lying in waves. It is found in fiſſures of lime-ſtone in Haycliff and Ladywaſh mines at Eyam, and in Oden at Caſtleton, in Derbyſhire. It is divided into two equal parts or ſlabs, by a line parallel to the ſides of the fiſſure, and theſe ſlabs are joined by two poliſhed faces, which ſeem to be in perfect contact without any coheſion. The ſurfaces are coloured with lead ore, or a ſubſtance very much reſembling it, but as thin as a covering from a black lead pencil. If a ſharp-pointed tool, which the workmen call a pick, is drawn over the vein with ſome force, the mineral begins to crackle like ſulphur excited by electricity; in a few minutes after which the laminæ explode with violence, and fly out as if they had had been blaſted with gun-powder, inſomuch that the weight of forty tons has been blown out together. Theſe dangerous effects deterred the workmen from proceeding for ſeveral years; but at length it occurred to them that this power might be uſed for the carrying on of their works with better advantage than by the common method of blaſting with gun-powder. Accordingly a workman makes a ſcratch with his tool upon the joint of the ſlickenſides, and runs away as faſt as he can, to eſcape the exploſion; which, it is ſaid, looſens as much of the rock as ten men would have brought away in three months, by the ordinary methods.

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* Obſervations on the Strata in Derbyſhire, p. 185.

CHAP. XV.

COMPOUND EARTHS.

Definition of this Genus.—Various compound Stones.

IN a ſtrict ſenſe all earths and ſtones, as they exiſt in nature, may be denominated compound, as there are none which are wholly ſimple. By compound earths, however, is here meant ſuch as are formed of two or more kinds of ſtony matter, and which in general conſtitute a maſs of an heterogeneous appearance. In treating of theſe ſubſtances, the arrangement of M. Daubenton appears the moſt perfect and commodious.

Mixed Stones,

OF TWO GENERA.

Quartz and ſcintillating ſpar	Granitin.
Quartz and ſchirl	Granitello.
Quartz and ſteatites	Quartzoſe ſteatites.
Quartz and mica	Micaceous quartz.
Tranſparent quartz and mica	Micaceous cryſtal.
Quartz in grit and gem ſtone	1 Garnet on grit ſtone. 2 Garnet in grit ſtone.

Quartz in grit and mica	Micaceous grit.
Quartz in grit and calcareous matter	1 Cryſtallized grit. 2 Grit in ſtalactites.
Quartz in ſand and opake ſtone	ſandy and ſiliceous breccias.
Quartz in ſand and ſchiſtus	ſcintillating ſchiſtus *hornſtone, trap.*
Quartz in ſand and zeolite	ſcintillating zeolite.
Scintillating ſpar and paſte, or cement, of ſchirl	ophites.
Semi-tranſparent ſtone, with opake ſtone	jaſpered agate, or agatized jaſper.
Schorl and mica	micaceous ſpathoſe ſchirl.
Schiſtus and mica	micaceous ſchiſtus.
Schiſtus and marble	Florence marble.
Serpentine and marble	1 green Egyptian marble. 2 ſea-green marble. 3 green antique marble. 4 green marble of Suza. 5 green marble of Varalta.
Ponderous ſpar and calcareous matter	alkaline ponderous ſpar.

OF THREE GENERA.

Quartz in ſand, ſchiſtus, and mica	Rough whet-ſtone.
Quartz, gem, and mica	garnet rock.
Quartzoſe paſte, ſcintillating ſpar in large fragments, and ſchorl	porphyry.
Quartzoſe paſte, ſcintillating ſpar in large fragments, and ſchorl	ſerpentine. *hard ſerpentine.*

Quartz, ſchirl, and ſteatites -	tuberculous rock.
Quartz, ſcintillating ſpar, and ſchirl - - - - - -	granite.

OF FOUR GENERA.

Quartz, ſcintillating ſcar, ſchirl and mica - - - - -	granite.
OF SEVERAL GENERA, MORE OR LESS IN NUMBER, UNITED IN BRECCIAS - - - - -	univerſal breccias.

DOUBLE BRECCIAS.

Varieties.	1 Fragments of porphyry, with a paſte of porphyry. 2 Fragments of granite, with a paſte of ſchorl.

Chap. XVI.

VOLCANIC PRODUCTS.

Lava.—Different Kinds.—Progreſs of a River of Lava.—Compound Parts of Lava.—Pumice Stone.—Baſaltes.—Trapp.—Terra Puzzolana.

I. LAVA is of very various appearance, according to its compoſition, and its more or leſs perfect vitrification. The materials of which lavas conſiſt, are the common ſubſtances to be found every where in the earth, namely, ſtones, metallic ores, clay, ſand, &c.; and as there is room for great variety in the combinations of theſe ſubſtances, the melted maſſes formed by them muſt in different circumſtances be very various. Some lavas are very compact, and receive a beautiful poliſh, exhibiting great variety of colours and forms. Others are extremely porous, and mixed with ſcoriæ or droſs. On the different conſiſtence of lavas depends their capacity for being converted into mould, capable of ſupporting vegetables. Some lavas have a tendency to crumble into duſt immediately on iſſuing from the crater; others are a perfect glaſs, and are calculated to reſiſt for a long time every approach towards diſſolution.

Lava, when firſt thrown out from the crater of a volcano, is an uniform liquid maſs, and flows down the ſide of the mountain with conſiderable rapidity. From loſs of heat, however, its ſurface is ſoon converted into a tough and black cruſt, which, as it becomes thicker, gradually impedes the progreſs of the fluid lava which is contained within it. This cruſt is frequently broken, when the ſtream of lava reſembles a river with maſſes of ice floating on its ſurface. Fluid lava ſometimes flows for a conſiderable diſtance, under the tenacious ſcum, and again appears beyond it in all its ſplendour. In the night time the courſe of the lava appears like flame, but no real flame ever exiſts, unleſs the lava in its progreſs happens to meet with combuſtible matter. In the day-time its courſe is marked by a thick white ſmoke.

Mr. Kirwan divides lavas into three kinds, the cellular, the compact, and the vitreous. All lavas are more or leſs magnetic, give fire with ſteel, are of a granular texture, and melt without the addition of other ſubſtances. The cellular lavas are ſuch as have undergone only the firſt and loweſt degree of fuſion, being juſt ſoftened and heated ſufficiently to expel the fixed air contained in the matter from which they are formed, which ſeems to be argillaceous ſlate; hence they abound in ſmall cavities occaſioned by the expanſion of that air. The ſpecific gravity of ſome lavas from theſe cavities is ſo ſmall, that they float for ſome time on water. From this circumſtance they have ſometimes been miſtaken for pumice-ſtone; but they differ from it, becauſe their texture is never filamentous. The perfectly vitrified lavas muſt have been expoſed to an immenſe heat, as they are very difficultly fuſed without addition. M. Sauſſure has ingeniouſly imitated all the different kinds of lavas, by different degrees of fuſion of the earthy ſubſtances from which they are formed. M. Bergman analyzed a ſpecimen of the perfect kind, and found an hundred parts to conſiſt of forty-nine of ſiliceous earth, thirty-five of argillaceous, four of calcareous earth, and twelve of iron.

The beds of lava are deepeſt and narroweſt near the crater, and broader and ſhallower as they advance, unleſs ſome valley intervenes. Pumice-ſtones lie at a ſtill greater diſtance; and from theſe obſervations, ſays Mr. Kirwan, extinguiſhed volcanoes may be traced. The quantities of matter thrown out of volcanoes at one eruption, are often ſo great as to cover a ſpace of country of many miles, and to be many years in cooling.

II. Pumice-stone ſeems to be rather a volcanic ejection than a volcanic product. Its colours are grey, white, and reddiſh brown. It is hard, rough, porous, conſiſts of ſlender fibres parallel to each other, is very light, and with difficulty gives fire with ſteel. It ſeems to have been originally an aſbeſtos decompoſed by the action of fire. One hundred parts contain from ſix to fifteen of magneſia, with a ſmall portion of calcareous earth; the remainder is chiefly ſilex. Pumice-ſtone ſwims on water. It is uſed to ſmooth rough ſurfaces, and, in a ſtate of powder, in various branches of manufacture, chiefly for poliſhing.

III. Basaltes is a ſtone of a dark grey colour, covered with a ferrugineous cruſt, and generally cryſtallized in opake triangular or polyangular columns. When it is amorphous*, and breaks into large, thick, ſquare pieces, it is called *trapp*. When heated red hot, and quenched in water, it becomes by degrees of a reddiſh brown. It melts without mixture into a perfect ſlag. One hundred parts contain fifty-two ſiliceous, fifteen argillaceous, three calcareous, two of magneſian earth, and twenty-five of iron. Baſaltes ſometimes is found in large columns with convex and concave articulations, ſo as to reſemble an artificial ſtructure: of this kind are the baſaltic pillars in Ireland, called the Giant's Cauſeway.

Glaſs, in cooling, has been known to aſſume the regular baſaltic form. Sir William Hamilton remarked, both in Sicily and Naples, that ſuch lavas as have run into the ſea are either formed into regular baſaltes, or have a great tendency to that form.

IV. Terra Puzzolana or Terras, is a volcanic production, of a grey, brown, yellowiſh or blackiſh colour, looſe, granular, or duſty and rough, porous and ſpongy, reſembling a clay hardened in the fire, and then reduced to a groſs powder. Its moſt diſtinguiſhing property is, that when mixed with about one-third of its weight of lime and water, it hardens very ſuddenly, and forms a cement which is more durable in water than any other. Its indurating power ſeems to ariſe from the dry ſtate of the half-baked argillaceous particles, which cauſes them to imbibe water very rapidly, and thus the deſiccation of the calcareous earth is accelerated. It is found not only in Italy, but alſo in France, in the provinces of Auvergne and Limoges, and alſo in England and elſewhere. According to Bergman's analyſis, one hundred parts contain from fifty-five to ſixty of ſiliceous earth, nineteen or twenty of argillaceous, five or ſix of calcareous, and from fifteen to twenty of iron.

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* Not of a regular form.

CHAP. XVII.

METALS.

Uſes of Metals.—Their Properties.—Weight, Opacity, Malleability, Ductility, Fuſibility.—Mix with each other.—Their Inflammability.—Calcination.—Entire and Semi-metals.—Perfect and imperfect.—Natural Hiſtory of Metals.—Working of Mines.—Aſſaying.—Smelting.—Union with Acids.—Action of other Subſtances on Metals.

METALLIC ſubſtances are valuable for their durability, their capacity of aſſuming and retaining all ſorts of forms and impreſſions; the cloſeneſs of their texture, which renders them capable of poliſh; the firm coheſion of their particles, which renders them highly proper for utenſils, where great ſtrength is required to be combined with moderate bulk. Several of the metals are alſo highly uſeful as medicines.

The firſt and moſt obvious property of metals is their remarkable weight, in which they exceed all other bodies. By this circumſtance they are diſtinguiſhed from earths; the lighteſt of metals, which is tin, being ſeven times the weight of water, whereas the heavieſt earth is only between four and five times the weight of water.

Metallic ſubſtances are by far the moſt opake of all bodies. The moſt opake ſtone divided into thin plates, has more or leſs of tranſparency, whereas gold is the only metal which admits of being reduced to ſuch a degree of thinneſs as to afford the ſmalleſt perceptible tranſmiſſion of light. Gold in leaf, which is about $\frac{1}{280000}$ part of an inch in thickneſs, tranſmits light of a lively green colour; but ſilver and braſs leaf are perfectly opake. The opacity of metallic bodies renders them exceedingly proper for reflecting the rays of light, as no bodies poſſeſs this property in ſo eminent a degree. Thus we obſerve that glaſs reflects objects very imperfectly, unleſs coated with metal, as in looking-glaſſes. The capacity of reflecting light depends on the degree of poliſh and the whiteneſs of ſurface, conſequently white metallic ſubſtances reflect a greater quantity of light, and are more brilliant, than thoſe which are coloured.

A property which ſeems to belong excluſively to metals, and yet not to all of them, is malleability. This conſiſts in a capacity of having their ſubſtance extended, and their ſurface increaſed, either in breadth or length, without being liable to fracture. The capacity, however, of being extended in length and breadth is not exactly the ſame, for metals which admit of extenſion under the hammer cannot always be drawn into wire, which property is diſtinguiſhed from the other by the term ductility. Beating always reduces metals to a ſtate of rigidity and brittleneſs. To remedy this, the metals are generally heated red hot, and cooled again ſlowly; in this caſe their malleability will be increaſed, and this is called annealing them. Crammer ſays, that if gold is annealed in this manner the leaf will be opake, and that the tranſmiſſion of light through ordinary gold leaf depends on ſmall cracks and flaws in the metal. If this aſſertion is true, it will in a great meaſure eſtabliſh the perfect opacity of metallic ſubſtances. Metals, when hammered, give out a degree of heat, and at the ſame time become brittle; and the only method of reſtoring their malleability is to expoſe them to the action of heat, and to ſuffer as much of this as poſſible to fix itſelf in their ſubſtance, by cooling them gradually. From theſe facts it is probable that the malleability of metals, as well as fluidity and elaſticity in general, depends on the particles of bodies being kept at a diſtance by the preſence of latent heat.

Metals are the beſt conductors of electricity of all bodies.

Metals are fuſible by heat, and one of them (mercury) is well known to exiſt in a ſtate of fuſion in the ordinary temperature of the atmoſphere. The particles of metals have a remarkably ſtrong attraction for each other, which is evinced by ſmall portions of metal, when in a ſtate of fuſion, having a tendency to aſſume a globular form.

Moſt metals will uniformly mix in all proportions with each other; the ſpecific gravities, however, of theſe compounds is ſcarcely ever ſuch, as would be mathematically deduced from the ſpecific gravities of the metals employed, on the ſuppoſition of their junction by ſimple contact. Mixtures of metals are more fuſible than might be expected from the degree of fuſibility of their component parts, and are therefore conveniently uſed as ſolders.

It is found that metals which, after having been fuſed, are ſuffered to cool gradually, evince a tendency to aſſume a regular figure, and to cryſtallize in general in an octahedral form.

Metals, in their ſplendid or *reguline* ſtate, have a conſiderable attraction for oxygen, and are in this reſpect nearly allied to the inflammable ſubſtances. Iron burns with a bright flame when heated to a certain degree, and immerſed in vital air; and a mixture of tin and nitre produces a violent deflagration. Zinc, when heated and acted on only by common atmoſpheric air, burns with a bright and vivid flame like phoſphorus. It is remarkable that mixtures of metals calcine more eaſily than the metals in a ſeparate ſtate. Thus a mixture of lead and tin, neither of which, when ſeparate, afford heat and light, in their mixture produce both, and the calcination is remarkably rapid. From the addition of oxygen the weight of the calx is greater than that of the quantity of the metal from which it was produced. In ſome metals, however, the attraction for oxygen is ſo weak (as is the caſe with the finer metals) that it is only by particular proceſſes that they can be combined with it. Metals united with oxygen loſe their ſplendour, malleability, and texture, and are denominated calces.

According to the old chemical theory, the calx of a metal was deemed a ſimple ſubſtance, and was called the earth or baſis of a metal; and it was ſuppoſed that this earth, united with phlogiſton, conſtituted the metal in its perfect ſtate. It is now, however, very ſatisfactorily proved, that the metallic ſtate is the more ſimple, and that the calx is a combination of the metal with oxygen. Metals are reduced from the calciform to the reguline* or metallic ſtate, by heating them in contact with ſubſtances which have a ſtronger attraction for oxygen than themſelves, as charcoal, tallow, &c.

Metals which are malleable are called entire metals; and thoſe which are brittle, ſemi-metals. Metals are alſo diſtinguiſhed into perfect and imperfect. The perfect are ſuch as are not calcined by being heated in contact with air, and are three in number, ſilver, gold, and platina: the other metals are calcined in thoſe circumſtances, and are called imperfect. It will eaſily be underſtood that theſe differences merely indicate different degrees of attraction for oxygen; and as in this reſpect, as well as in regard to malleability, there are numerous gradations among the metals, it will be neceſſary to treat ſeparately of each metal as a diſtinct ſubſtance. I ſhall begin with ſuch metals as have moſt reſemblance to the earths, and are therefore called ſemi-metals, and conclude with thoſe which have the metallic properties in the higheſt perfection.

Thoſe metallic bodies with which we are at preſent acquainted, and which we can reduce to the metallic or reguline ſtate, are the following ſeventeen:

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* The name *regulus* was given by the fanciful alchemiſts to the metallic button, found in the bottom of the crucible after an aſſay, from the idea that this button contained gold, which they called the *king* of metals.

1. Arſenic.
2. Molybdena.
3. Tungſtein.
4. Manganeſe.
5. Nickel.
6. Cobalt.
7. Biſmuth.
8. Antimony.
9. Zinc.

Semi-metals.

10. Iron.
11. Tin.
12. Lead.
13. Copper
14. Mercury.

Imperfect Metals.

15. Silver.
16. Gold.
17. Platina.

Perf. Met.

Of theſe the nine firſt are called ſemi-metals, from defect of malleability; the five following imperfect metals, from their being calcineable by heat and air; and the three laſt, perfect, from their capacity of reſiſting the action of heat and air without change.

Metals exiſt in a ſtate of nature in four different forms.

1. They are found in a native ſtate of purity, with all the metallic properties. Gold is always found in this ſtate; ſilver, copper, mercury, biſmuth, and arſenic often; iron ſeldom; and lead, zinc, and regulus of antimony ſtill more rarely.

2. Metals are found in the ſtate of earth or calx, without the metallic aſpect, and often reſembling ochres.

3. The common ſtate, however, in which metals are found is that of ores. In this ſtate they are either combined with ſulphur or with ſome metal, the moſt common of which is arſenic *.

4. The laſt ſtate in which metals are found, is that of a combination with ſaline ſubſtances, and al-

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* In this and the following ſtate they are ſaid, in technical language, to be *mineralized*; that is combined with ſome other mineral ſubſtance.

moſt always acids. The vitriolic acid is moſt frequently found combined with metals, viz. zinc, lead, copper, and iron. The carbonic acid is alſo a common mineralizer, and the arſenical and phoſphoric acids have likewiſe been diſcovered in combination with metals.

Metallic ſubſtances are more commonly found in mountains than in plains, and almoſt always in ſuch mountains as form continued chains. It is in the ſtratified mountains that metals moſt abound, where the inclination of the ſtrata, in conſequence of the convulſions of nature, brings a variety of ſubſtances into view, which muſt otherwiſe have been for ever concealed beneath the reach of human inveſtigation. There are entire mountains which conſiſt of iron ore, but in general the metallic part of a mountain is very inconſiderable in proportion to the whole. The ores ſometimes run parallel to the ſtony ſtrata; the layer on which the ore is placed is called the bed or floor of the mine; the other which covers it, is called the roof. Sometimes, however, the metallic ſtrata, which are always more irregular than the other ſtrata of which the mountain is compoſed, interſect the bodies which ſurround them in a variety of directions. The metallic ores are accompanied with ſtony matters, which ſeem to have been formed at the ſame time. Theſe ſtones are uſually quartz and ſpar; they are called the rider or matrix * of the metal, and muſt neither be confounded with the mineralizing ſubſtance which is

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* So called from its frequently incloſing the ore. The ſparry matters are alſo ſometimes called by mineralogiſts *gangues*.

intimately combined with the metal, nor with the general maſs of ſtone, of which the mountain containing the metal is compoſed. It is obſerved that the vegetables which grow on metalliferous mountains are dry, the trees ſmall, ſinuous, and deformed, and the ſands often exhibit metallic colours. Mineral metallic ſprings are uſually found in the vicinity; by the examination of which, and of the ſands over which they flow, a tolerably accurate judgment may be formed of the metallic contents of the neighbouring ſtrata. When metallic veins appear at the ſurface of the earth, the ground may be broken into with great probability of advantage, and the boring inſtrument, by bringing up the ſubſtances which compoſe the internal parts of the mountain, together with the metallic minerals, ſerves to ſhew their quality, as well as the reſiſtance which may be expected in digging.

Before a metallic vein is wrought with a view to profit, it is neceſſary to aſcertain the proportion of metal contained in it, and this is called aſſaying. In theſe ſmall trials the fuſibility of the maſs is increaſed by the addition of three times the quantity of the black flux, which is made by burning together two parts of tartar with one of nitre. The alkali of this compound increaſes the fuſibility of the ſtony matter mixed with the ore, and conſequently affords the metal an opportunity of ſeparating from it; while the charcoal contained in it, and which proceeds from the impurity of the tartar, abſtracts the oxygen of the ore, and reduces the metal to a reguline form.

When the operation has been properly performed, the metal, or regulus, is found in the form of a button at the bottom of the maſs, and being weighed ſhews the proportion of metal contained in the ore.

This method is uſed in reducing ſmall quantities, as in aſſaying of ores, but would be too expenſive in large operations. They then mix the ores or calces with the fuel, but let as little air as poſſible paſs through it, as this would tend to re-calcine the metal. To prevent this effect, a particular ſort of furnace is employed, in which charcoal is chiefly uſed.

It frequently happens that the ſame minerals contain the perfect metals mixed with the imperfect; theſe are ſeparated both in the ſmall and large way by heating the mixed maſs in contact with air. By this operation the imperfect metal is reduced to a calx, and leaves the perfect metal in a ſtate of purity. If the remaining metallic matter is ſtill a compound, and contains two of the perfect metals, theſe are ſeparated by expoſing them, with as large a ſurface as poſſible, to the action of a menſtruum, which has the property of diſſolving one of them without the other.

There is alſo a method of aſſaying in the humid way, by ſubmitting the ores to the action of different acids; but this is not ſo practicable as the other.

In the extraction of metals in the large way, the ore is pounded, waſhed, roaſted, ſmelted, and refined. By pounding, the ſtony matters are ſeparated from the metallic, and the whole being then waſhed on inclined planes or tables, the ſtony matter being lighter is waſhed away, while the metallic remains behind. The roaſting or burning is intended to expel the volatile matters. Ores which contain much ſulphur muſt be roaſted in the open air, but ſuch as contain but little may be roaſted in the furnaces which afterwards ſerve to fuſe them. Some ores are fuſible alone, others require to be mixed with different fluxes. The methods of refining metals are extremely various, and depend on particular chemical affinities, which will be mentioned under the head of each metal.

The ſalts, and of them the acids in particular, have great effect on metals. Metals unite with acids into compounds, many of which cryſtallize. The corroſiveneſs of the acid is abated by its union with the metal, but not in ſo great a degree as by its union with the alkalies or earths. Neither is the point of ſaturation ſo well marked in the union of an acid with a metal as with an alkali. The ſame acid may, in many caſes, be united to the ſame metal in different proportions; when the acid is in exceſs the maſs is deliqueſcent, when it is deficent it ſeems to produce little other effect on the metal than to deſtroy its texture, and reduce it to a friable and earthlike ſtate.

Every metal, however, is not diſpoſed to unite with every acid, though ſome unite with all; others with only one acid. The order alſo in which the acids attract the metals is different from that in which they attract the alkalis. Metals attract the muriatic acid moſt ſtrongly, next the vitriolic, and laſt the nitrous. Metals which diſſolve in the ſame acid differ very much in the force with which they adhere to it, ſo that they may be employed to precipitate one another. Thus, if we add to the ſolution of ſilver in aqua-fortis, quickſilver, it precipitates the ſilver; copper, the quickſilver; iron or lead, the copper; and zinc, which precipitates theſe, may itſelf be precipitated by an alkali.

The ſolution of metals in the acids is attended with the eſcape of an elaſtic vapour, and an efferveſcence. This was formerly adduced among the proofs for the exiſtence of phlogiſton, which, united with a ſmall quantity of the water or acid, was ſuppoſed to conſtitute this elaſtic fluid, at the ſame time that the metal, by its loſs, was deprived of its ſplendour, &c. This appearance is now proved to ariſe from a decompoſition either of the acid or the water, and the elaſtic fluid differs in different caſes, according to the ſource from which it derives its origin; when it ariſes from the decompoſition of water, it is hydrogen or inflammable gas, when from that of the nitrous acid, nitrous gas, &c. Before the metal can be diſſolved, it is neceſſary that it ſhould be oxygenated; and therefore when its attraction is ſufficiently ſtrong, it decompoſes the acid or the water, by abſtracting their oxygen. It has been already remarked, that the muriatic acid has the ſtrongeſt attraction for metals, and the nitrous leſs than either that or the vitriolic. From merely obſerving the action of theſe acids on metals, however, a different concluſion might be drawn, for the nitrous acid acts with violence and rapidity in compariſon with the other two; and the muriatic, when in its pureſt ſtate, has the leaſt action of the three. This ſeeming inconſiſtency depends on the different degrees of attraction which the baſes of the different acids have for oxygen. The reaſon, therefore, why ſome metals cannot be diſſolved in particular acids, is, that they have not a ſufficiently ſtrong attraction for oxygen to decompoſe the acid. If we ſeparate a metal from an acid by any ſubſtance which is not capable of depriving it of oxygen, we always obtain it in a calcined ſtate. Thus gold, if precipitated from its ſolution in aqua regia by an alkali, is a calx; but if precipitated by any of the inflammable ſubſtances, as aromatic oils or ſpirits of wine, or by another metal, it appears in the metallic form. If metals are calcined previous to being united with acids, they produce no eſcape of gas, becauſe being already furniſhed with oxygen, they have no tendency to decompoſe the acid.

Light appears to alter the colour and brilliancy of ſome metallic matters, independently of the action of air; for when expoſed to light in tranſparent veſſels well cloſed, they become tarniſhed, and loſe their metallic brilliancy.

Heat applied to metals produces no other effects than expanſion and fuſion, if the air is completely excluded, unleſs carried to ſuch a degree as to volatilize them; but even in that caſe, when the heat ceaſes to act, they return to their original ſtate. Metals, on being converted into vapour, boil like other fluids, and even gold and ſilver are capable of this ſtate when acted on by a large concave mirror.

Moſt of the combuſtible bodies act on metals. Inflammable gas gives them a deeper colour, and is capable of reducing ſome of them to the metallic ſtate. Sulphur, and its combinations with alkalies, called hepars, act powerfully on metals.

From what is hitherto known of metals, there is every reaſon to believe that they are ſimple ſubſtances.

CHAP. XVIII.

ARSENIC.

Natural Hiſtory of Arſenic.—Mode of reducing it to the metallic Form.—White Enamel.—Orpiment.—Realgar.—Its Uſe in Medicine.—A dreadful Poiſon; how to detect it in the Body.—A Remedy for the Poiſon of Arſenic.

ARSENIC is often found native, in black heavy maſſes, but not very brilliant. It has ſometimes the metallic luſtre, and reflects the colours of the rainbow; in its fracture it is more brilliant than at its ſurface, and ſeems compoſed of a great number of ſmall ſcales. Native arſenic is very eaſily known, when it has the metallic brilliancy and ſcaly texture. Arſenic, however, is more frequently found in the form of flowers, or mixed with certain earths. Cobalt ores contain much arſenic, and that which is commonly ſold is brought chiefly from the cobalt-works in Saxony. The ore is thrown into a furnace, reſembling a baker's oven, with a flue or horizontal chimney, nearly two hundred yards long, into which the fumes paſs, and are condenſed in the form of a grey or blackiſh powder. This is refined by a ſecond ſublimation in cloſe veſſels, with a little pot-aſh to detain the impurities. As the heat is conſiderable, it melts the flowers into thoſe white cryſtalline maſſes which are met with in commerce.

The regulus is obtained from this ſubſtance, which is a calx of arſenic, by heating it with one-tenth of its weight of charcoal, or of any unctuous matter. The mixture is put into a tall veſſel, and a gradual and gentle heat applied to the lower part of it, while the upper is kept cool by the air. The arſenic, when nearly red hot, parts with its oxygen, and riſes to the upper part of the veſſel, where it is condenſed in the metallic form. To give it, however, its perfect metallic ſplendour and opacity, the ſublimation muſt be repeated.

The regulus of arſenic is of a bright yellowiſh white colour, very ponderous and friable, and ſubject to tarniſh and become black on expoſure to air. If heat is applied to the regulus in contact with air, it is volatilized before it melts, and is at the ſame time imperfectly calcined. The fumes are dangerous, and have a ſtrong and offenſive ſmell, reſembling that of garlic.

The white calx of arſenic is ſo far in a ſaline ſtate as to be ſoluble in eighty times its weight of cold, or fifteen times that of boiling water. When diſtilled with the nitrous acid, it decompoſes that fluid by depriving it of part of its oxygen. The arſenic, by this addition of oxygen, is reduced to the ſtate of an acid leſs volatile than either the regulus or calx, but retaining the form of a white concrete ſubſtance. The oxygenated muriatic gas likewiſe reduces arſenic to the ſtate of an acid.

Arſenic readily melts with other ſubſtances ſo as to form glaſs, and even promotes their fuſion. At firſt it always renders the glaſs milky, but by a continuation of heat the arſenic evaporates, and the glaſs becomes quite tranſparent. It is an ingredient in the white enamel dial plates; and it forms thoſe white ſpirals which are common in the ſtalks of wine-glaſſes.

Sulphur unites readily with arſenic into a compound more fuſible than the arſenic itſelf. Orpiment is a combination of arſenic and ſulphur, of a yellow colour. It is found naturally in the earth, generally of an irregular form, and compoſed of ſhining flexible laminæ. Its ſpecific gravity, according to Kirwan, is 5,315, who alſo aſſerts that it contains one-tenth part of its weight of ſulphur. The ſame author mentions, that realgar, or the red combination of arſenic and ſulphur, contains ſixteen parts of ſulphur in the hundred, and is of the ſpecific gravity of 3,225. Chaptal, however, obſerves that the difference between realgar and orpiment does not conſiſt in the proportions of ſulphur, nothing more being neceſſary in order to convert orpiment into realgar, than expoſure to a ſtrong heat. The violent action of arſenic on the animal machine is much abated by combination with ſulphur. Common white arſenic has ſometimes been ſucceſsfully uſed in doſes of one-twelfth or one-ſixteenth of a grain. Received, however, in any conſiderable quantity into the body, it produces dryneſs of the mouth, heat in the throat, excruciating pains in the bowels, attended ſometimes with vomiting of blood, cold ſweats, &c. On diſſection, the bowels are found inflated and corroded. Many black and livid ſpots appear on the ſtomach and ſmall inteſtines,

tines, ſometimes gangrenous. But theſe ſigns are not altogether to be depended on. Some of the arſenic is frequently found, and may be eaſily diſtinguiſhed. The powder is heavy, and eaſily ſeperates from the lighter contents of the bowels, by waſhing with water; the arſenic always falling to the bottom. A very little of this is ſufficient to give the ſmell of garlic, and tinge copper white, if heat is applied to it.

It was formerly uſual to give mucilaginous drinks, or milk or mild oils, to perſons poiſoned by arſenic. But Navier, a phyſician of Chalons, who has made experiments to aſcertain the beſt remedies againſt the poiſon of arſenic, has diſcovered a ſubſtance which combines with it in the humid way, and deſtroys, in a great meaſure, its cauſticity. This ſubſtance is the calcareous or alkaline liver of ſulphur, and is ſtill better adapted to the intention, when it holds a ſmall quantity of iron in ſolution. When this martial hepar is poured into a ſolution of arſenic, it is decompoſed without emitting any ſmell, becauſe the arſenic combines with the ſulphur, and forms orpiment, and at the ſame time unites with the iron. Navier preſcribes a dram of the liver of ſulphur in a pint of water, of which he directs a glaſs to be taken at a time; or five or ſix grains of dry liver of ſulphur may be given in pills, a glaſs of warm water being given after each pill. When the firſt ſymptoms are diſſipated, he recommends the ſulphureous mineral ſprings. Navier likewiſe approves the uſe of milk, becauſe it diſſolves the arſenic as well as water, but he condemns the uſe of oils, which have not that property.

Arſenic ſhews a ſtrong diſpoſition to unite with all the metals except platina. By a mixture of it in its ordinary ſtate with copper, a metal is produced reſembling ſilver. It generally gives metals a white colour, and renders them brittle.

CHAP. XIX.

MOLYBDENA.

Short Account of this Semi-metal.—May be reduced to an Acid.—A ſcarce Mineral.

THIS is a mineral ſubſtance, which has till lately been confounded with plumbago; but is now found to be a combination of a particular metallic ſubſtance with ſulphur. It is of a blackiſh colour, and conſiſts of ſhining laminæ, which have a degree of flexibility, ſo as to be very difficultly reduced to powder.

Molybdena reduced to its metallic form reſembles lead in colour and ſpecific gravity, but is very brittle, eaſily calcined and volatilized, and will not mix with lead when in fuſion.

Molybdena is capable of being oxygenated ſo far as to become an acid, in which ſtate it is a concrete body, white and pulverulent, reſembling chalk. This acid, heated with ſulphur in a particular manner, is capable of being converted into a ſubſtance in every reſpect the ſame as native molybdena.

This mineral is ſcarce. It is diſtinguiſhed from black lead by a more ſhining, ſcaly appearance; and it marks paper with a more brilliant ſtroke.

CHAP. XX.

TUNGSTEIN.

The Ore of Tungſtein confounded with that of Tin.—Where found. —Mode of reducing it to the reguline or metallic State.

TUNGSTEIN or wolfram is a particular metal, the ore of which has frequently been confounded with that of tin. The ſpecific gravity of this ore is to water as ſix to one; in its form of cryſtallization it reſembles the garnet, and varies in colour, from a pearl white to yellow and reddiſh; it is found in ſeveral parts of Saxony and Bohemia. The mineral called wolfram, which is frequent in the mines of Cornwal, is likewiſe an ore of this metal; in all theſe ores the metal is oxydated; and in ſome of them it appears to be oxygenated to the ſtate of an acid, being combined with lime into a true tungſtat of lime*.

The calx of this metal cannot be obtained free from the bodies with which it is united, without a particular proceſs, which conſiſts in the alternate application of volatile alkali and marine acid, and the ſubſequent addition of the nitrous acid, as long as red fumes are produced. This calx or imperfect acid has the colour of brimſtone, and is ſcarcely ſoluble in water. By being ſubmitted in a crucible with charcoal, to a ſtrong heat, a regulus of tungſtein may be obtained, which is a brown maſs, conſiſting of a congeries of metallic globules; and again becomes yellow by calcination. The regulus is not acted on by the vitriolic and marine acids; the nitrous acid, however, and aqua-regia, act on it, and by oxygenating it reduce it to its calciform ſtate.

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* Lavoiſier's Chemiſtry.

M. Lavoiſier recommends the following proceſs for obtaining the calx of tungſtein: Mix one part of ore of tungſtein with four parts of mild vegetable alkali, and melt the mixture in a crucible, which ought to be of platina; then powder, and pour on twelve parts of boiling water; add pale nitrous acid, and the tungſtenic acid precipitates in a concrete form. Afterwards, to inſure the complete oxygenation of the metal, add more pale nitrous acid, and evaporate to dryneſs, repeating this operation as long as red fumes are produced from the acid.

Chap. XXI.

MANGANESE.

Natural Hiſtory of Manganeſe.—Its Effects on Glaſs.—Regulus or Metal.—Black Wad.—Manganeſe contained in Vegetables.—Uſes in the Arts.

THIS metal is almoſt always found in the ſtate of calces, which vary much in colour and appearance; they are white, blue, yellow, red, dark green, and black, according as they are united with more or leſs oxygen, or contaminated with foreign ſubſtances. The darker coloured the ores, the more oxygen they may be ſuppoſed to contain, as any proceſs which deprives them of this principle always renders them paler. Manganeſe is alſo found cryſtallized in a variety of forms. Many naturaliſts, judging by their colour, and the ochry * cruſt with which they are often ſurrounded, have ranked the calces of manganeſe among the iron ores. The black calx of manganeſe gives a violet, purpliſh, and ſometimes a reddiſh tinge to tranſparent glaſs; but when added in a ſmall quantity to that which has a blueiſh or greeniſh caſt, it produces only a ſlight duſkineſs, without a predominancy of any colour.

The regulus of manganeſe is very difficultly obtained. Its colour is a duſky white, but its maſſes are irregular and uneven from imperfect fuſion. Its fracture is bright and ſhining, but it ſoon tarniſhes and becomes blackiſh on expoſure to air. When pulverized it is always magnetic, though it has not this property in the maſs. If expoſed to air, particularly in moiſt weather, it ſoon crumbles into a blackiſh brown powder, which is ſomewhat heavier than the regulus from which it was produced.

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* Ochre being an iron ore.

The calces of manganeſe retain their oxygen ſo weakly, that part of it may be expelled by the application of a ſtrong heat. They alſo part with their oxygen to unctuous oils. If half a pound of that ore of magnaneſe called black wad is well dried before the fire, afterwards ſuffered to cool for about an hour, and then mixed with two ounces of linſeed-oil, ſmall clots will be formed, and in little more than half an hour the whole will gradually grow hot, and at laſt burſt into flame.

Manganeſe ſeems to be contained in the aſhes of moſt vegetables, and to it the blue or greeniſh colour of calcined vegetable alkali is owing. If three parts of alkali of tartar, one of ſifted aſhes, and one-third of nitre, are melted together, they form a dark green maſs, which being diſſolved in water, affords a beautiful green ſolution; this being filtered, on the addition of a few drops of vitriolic acid becomes red, and after a few days a brown powder is ſeparated, which has all the properties of manganeſe.

The vitriolic, nitrous, and marine acids diſſolve the regulus of manganeſe in the uſual ways. The black calx is nearly inſoluble in the acids, unleſs it is deprived of part of its oxygen by the addition of ſome inflammable or metallic ſubſtance. The marine acid, however, digeſted with the black calx of manganeſe, diſſolves it without addition, in proportion as it loſes ſome part of its oxygen. The oxygen uniting with part of the muriatic acid, renders it volatile, and converts it into oxygenated muriatic acid. The permanent ſolubility of the black calx of manganeſe in the acids, depends on the acid, or ſome ſubſtance mixed with the acid, abſtracting part of its oxygen. The manganeſe ſeparated from its ſolution in acids by alkalies, is in the form of the white or imperfect calx, which, however, becomes black by being heated in contact with air.

In the dry way the calx of manganeſe combines with ſuch earths and ſaline ſubſtances as are capable of undergoing fuſion in a ſtrong heat. The violet colour which it communicates to glaſs is liable to be deſtroyed by combuſtible ſubſtances. From this circumſtance we may conclude, that the property of colouring glaſs depends on the calciform ſtate of this metal, and that it is loſt when any body abſtracts its oxygen and reduces it to a regulus.

Manganeſe in its metallic form will not unite with ſulphur, but melts readily with moſt of the metals. Gold and iron are rendered more fuſible by a due addition of manganeſe, and the latter metal is rendered more ductile.

Manganeſe has hitherto been uſed chiefly by glaſs-makers and potters; but the important diſcoveries of the effect of oxygenated muriatic acid, prepared by means of manganeſe, in bleaching, will no doubt extend its utility to ſeveral other manufactories.

CHAP. XXII.

NICKEL.

Natural Hiſtory of Nickel.—Metal how obtained.—Detonates with Nitre.—Has a ſtrong Repulſion for Silver, and Attraction for Sulphur.—A uſeleſs Mineral.

THIS metal derives its name from the mineral in which it is contained. It is found united with ſulphur and arſenic. Its ores have a coppery red colour, are almoſt always covered with a greeniſh grey efflorefcence, and have been miſtaken for ores of copper. The ores of nickel often contain cobalt and iron. Moſt of the ſulphur and arſenic may be driven off by long continued roaſting, and the occaſional addition of charcoal, which prevents the arſenic from being rendered more fixed by calcination; and the green calx which remains may be fuſed by the ſtrongeſt heat of a ſmith's forge, together with two or three times its weight of black flux. By theſe means a regulus may be obtained, which, however, is very far from being pure, as it contains much arſenic, cobalt, and iron. In this ſtate it is of a white colour with a tinge of red, and has a granulated texture. When this metal is rendered more pure by treatment with ſulphur, charcoal, volatile alkali, and nitre, it becomes extremely infuſible, loſes ſomewhat of its reddiſh tinge, and acquires a conſiderable degree of malleability. Nickel may be freed from ſulphur and arſenic, but it cannot be accurately purified from cobalt and iron, for it is conſiderably attracted by the magnet, and gives ſigns of containing cobalt, after the utmoſt pains have been taken to obtain it in a pure ſtate. It affords a blue ſolution with volatile alkali, and in nitrous acid its ſolution is of a full green.

From its magnetic property, nickel has been conſidered as a modification of iron; and by its producing a blue colour with volatile alkali, it has been ſuppoſed to be an alloy of copper with various metallic ſubſtances. Chemiſts, however, are now very generally agreed in conſidering nickel as a diſtinct metallic ſubſtance.

M. Sage affirms, that when four parts of oil of vitriol are diſtilled with one part of the regulus of nickel in powder, the ſulphureous acid paſſes over; the reſidue is greyiſh, and, being diſſolved in diſtilled water, produces the moſt beautiful green colour. The cryſtals obtained from this ſolution are foliated, and of the colour of an emerald. According to M. Arvidſon, the vitriolic acid forms a green ſalt, in decahedral cryſtals, with the calx of nickel.

This calx is eaſily ſoluble in the nitrous acid, and cryſtallizes in rhombic cubes. According to M. Sage, all the other ſolutions of nickel, or its calx, either in the muriatic acid or in vegetable acids, are more or leſs green. It has been ſaid, that the nickel contained in cobalt occaſions the ſubſtance known under that name to produce a green colour with acids. Nickel differs from cobalt in not being ſeparated from acids by the addition of any other metal.

Nickel detonates * with nitre; this detonation afforded Mr. Arvidſon a method of diſcovering the preſence of cobalt, which no other proof has rendered ſenſible. Nitre has likewiſe the property of augmenting the intenſity of the hyacinthine colour, communicated to glaſs by the calx of nickel. The calx of nickel, fuſed with borax, likewiſe produces a hyacinthine colour. The calces of nickel are of a green colour.

The moſt remarkable properties of the regulus of nickel are, a repulſion for ſilver, and a ſtrong attraction for ſulphur. It has ſo ſtrong an affinity for ſulphur, as to attract it from moſt other metals.

Nickel combines by fuſion with ſulphur into a hard mineral of a yellow colour, with ſmall brilliant plates, which, when ſtrongly heated in contact with air, deflagrates and emits very luminous ſparks, ſimilar to thoſe afforded by iron when forged. Cronſtedt informs us that this metal is ſoluble in liver of ſulphur, and forms a compound reſembling the ores of copper. The ſulphur can only be ſeparated from nickel by repeated fuſions and calcinations.

Cronſtedt affirms that nickel forms, with biſmuth, a brittle and ſcaly regulus. Nickel has not yet been applied to any uſe.

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* Inflames, and explodes ſuddenly.

CHAP. XXIII.

COBALT.

Natural Hiſtory of Cobalt.—Analogy between this Metal and the blue colouring Matter of Vegetables.—Mode of aſſaying it.—Mines of Cobalt.—Smalt, or Powder Blue.—Uſes of Cobalt in the Arts.—Curious ſympathetic Ink.—Changeable Landſcape.—Union with other Metals.

COBALT has never been found native, that is in a metallic ſtate, but is almoſt always calcined or united with arſenic, the arſenical acid, ſulphur, iron, vitriolic acid, &c. Minerals containing cobalt are frequently of a pink colour, which ariſes from the preſence of arſenical acid, and its colour is deſtroyed by fire, in proportion as the acid is diſſipated. When united with vitriolic acid, it alſo is ſometimes reddiſh: the effect of acids on cobalt points out an analogy between it and the blue colouring matter of vegetables.

To aſſay cobalt ores, the operations of pounding, waſhing, and roaſting muſt be all employed. The cobalt remains in a ſtate of black calx, more or leſs deep with reſpect to colour; this is mixed with black flux and a ſmall quantity of decrepitated ſea ſalt; the fuſion is performed in a forge heat in a covered crucible, which muſt be ſlightly agitated, to precipitate the metal as ſoon as the fuſion is complete. The metallic button is ſometimes found to conſiſt of two diſtinct ſubſtances, cobalt being uppermoſt, and biſmuth beneath; a ſtroke of the hammer readily ſeparates them.

The regulus of cobalt is of a whitiſh grey or ſteel colour, hard, brittle, of a dull cloſe-grained fracture, and moderate ſpecific gravity. It has about the ſame degree of fuſibility as copper; does not eaſily become calcined; and its calx is of ſo deep a blue colour as to appear black. Cobalt expoſed to heat does not melt till it is well ignited. It appears to be very fixed in the fire, and it is not known whether it can be volatilized in cloſe veſſels. If it is ſuffered to cool ſlowly, it cryſtallizes in needle-formed priſms, placed one on another, and united in bundles. Cobalt, melted and expoſed to the air, becomes covered with a dull pellicle, which is a calcination analogous to the ruſting of iron.

The richeſt mines of cobalt are in Saxony. The ore which is worked there in the large way contains a conſiderable quantity of arſenic, which is driven off by heat, but is collected in long channels of wood, and preſerved for ſale, as was intimated before. After the ore has been kept ſome time in the furnace, there remains a dark friable ſubſtance, which is the cobalt in the form of a calx, and called *zaffre*. This is mixed with the ordinary ingredients of glaſs, and melted with a violent heat, ſo as to produce the common blue powder called ſmalt, which is a pounded glaſs. Some of this is mixed with flints and alkaline ſalts, and then ſold under the name of ſapphire to the manufacturers of porcelain and common Delft ware, for tinging their glazing blue.

Powder blue, or azure, is obtained by grinding ſmalt in mills, and afterwards waſhing it in water. This laſt operation is performed in a caſk filled with water, and pierced with three openings at different heights. The water of the uppermoſt cock carries out the fineſt blue. The larger particles fall more ſpeedily, and the azure brought out by the water of the three cocks forms the different degrees of fineneſs, known by the names of azure of the firſt, ſecond, and third fires. Powder and ſtone blue, uſed by laundreſſes, is a preparation made by the Dutch from the coarſe ſmalt.

A ſmall quantity of the calx of cobalt tinges glaſs of different ſhades, according to the quantity uſed. One grain of cobalt to ſeven thouſand of the glaſs, renders it very blue: hence the paſtes in imitation of ſapphire are produced. Stained flint glaſs is made by ſixteen parts of ſand, eight or ten of pearl-aſh, and metals in different proportions.

Cobalt diſſolves readily in aqua-fortis, both in its metallic ſtate and in that of a calx. If we take a ſolution of its calx in that fluid, and add a quantity of water to it, and then let it ſtand a while, it turns red, and on evaporation forms cryſtals of the ſame colour, and by this it may be diſtinguiſhed from all other metals. This ſolution forms a red ſympathetic ink, which appears on the paper by heat, and again diſappears by cold.

Aqua-regia diſſolves cobalt more eaſily than the muriatic, but not ſo eaſily as the nitrous, acid. This ſolution is a celebrated ſympathetic ink. If it is diluted with a ſufficient quantity of water to prevent

vent its action on paper, and then uſed to write with, the letters are inviſible as ſoon as the clear ſolution becomes dry; but if the paper is held to the fire for a ſhort time, they appear of a fine green colour; which again diſappears by removing it, and ſuffering it to cool. If held to the fire too long, the green colour becomes permanent. From theſe two inks a very curious changeable landſcape may be made. The trunks of trees, houſes, &c. may be painted with common colours, ſo as to repreſent winter. The verdure, the fruits, and the flowers may be depicted in different ſhades of the two inks. On aproaching the fire the landſcape will gradually be changed from a winter to a ſummer ſcene. The trees will begin to ſhoot out their foliage, and the flowers and the fruits will, by degrees, aſſume the appearance of maturity. The vivid parts will again fade, on being removed from the heat, and the landſcape reſume the wintry aſpect.

It was formerly thought that the green colour produced by heat in the ſympathetic ink of cobalt, aroſe from the metallic ſalt being cryſtallized, and afterwards attracting a ſufficient quantity of water from the cold air to diſſolve it, and cauſe it to diſappear; but it is proved, that the marine ſalt of cobalt, diſſolved in water, aſſumes the ſame colour when expoſed to a certain degree of heat.

The vitriolic acid in a concentrated ſtate does not diſſolve cobalt without the aſſiſtance of heat, when the acid is decompoſed, and comes over in ſulphureous fumes. The cobalt is in part calcined, and in part converted into a cryſtalline ſalt ſoluble in water, and which may be precipitated by lime and by alkalies, in the form of a roſe-coloured powder or calx. Diluted vitriolic acid acts upon the calx of cobalt, and forms the ſame ſalt.

Cobalt unites with all the metals except ſilver, lead, quickſilver, and biſmuth, but does not produce any remarkable or uſeful compound with any. It is ſeparated from acids by zinc in the form of a dark-coloured powder, but not by iron.

A mixture of nickel with the calx of cobalt very much injures the colour which the latter communicates to glaſs. The following proceſs is one of the beſt for ſeparating them when the cobalt is in conſiderable quantity: Saturate a ſolution of the roaſted ore in nitrous acid, and drop it into liquid volatile alkali. The cobalt then is inſtantly re-diſſolved, and aſſumes a garnet colour; when filtered a grey powder remains on the filter, which is the nickel. The cobalt may be precipitated by any acid.

CHAP. XXIV.

BISMUTH.

External Qualities of Biſmuth.—A powerful Diſſolver of Earths.—Pearl White, a pernicious Coſmetic.—Curious Experiment.—A metallic Compoſition, which melts in boiling Water.—Various Uſes of Biſmuth in the Arts.

BISMUTH is extremely brittle, ſo that it may be eaſily ſeparated, and even reduced to powder by the hammer. When broken it exhibits at the place of fracture large ſhining plates, diſpoſed in a variety of directions. It is conſiderably ponderous, and is of a yellowiſh white colour; when in thin plates it is in ſome degree ſonorous. It is very fuſible, and melts at a temperature not exceeding 460° of Farenheit.

Biſmuth is ſcarcely altered by expoſure to air and light. In cloſed veſſels it ſublimes without alteration; it cryſtallizes the moſt eaſily of any metallic ſubſtance. If biſmuth is kept in fuſion in contact with air, its ſurface becomes covered with a pellicle, which changes into an earth of a greeniſh grey or brown, named calx of biſmuth. Nineteen drachms of biſmuth, calcined in a capſule of glaſs, afforded M. Baumè twenty drachms thirty-four grains of calx. Biſmuth heated to redneſs burns with a ſmall blue flame, ſcarcely ſenſible. Its calx evaporates in the form of a yellowiſh ſmoke, which condenſes on the ſurface of cold bodies, into a powder of the ſame colour, called flowers of biſmuth. This powder owes its volatilization only to the rapidity with which the biſmuth burns; for if it is expoſed in cloſe veſſels to fire, it melts into a greeniſh glaſs without ſubliming. Geoffroy the younger obſerved, that the flowers of biſmuth, which riſe the laſt, are of a beautiful yellow, reſembling orpiment.

The grey or brown calx, the yellow flowers, and the glaſs, are nothing more than combinations of this metal with the baſe of vital air, which are not reducible without addition.

Calx of biſmuth is one of the moſt powerful diſſolvers or liquefiers of earthy bodies, or of the calces of other metals, and gives a yellowiſh tinge to glaſſes, into the compoſition of which it enters. Biſmuth is alſo readily calcined by nitre, but without detonation. The alkalies have little effect on biſmuth; when applied, however, in a cauſtic ſtate, they diſſolve part of the metal.

The vitriolic and muriatic acids do not act on biſmuth, unleſs aſſiſted by heat. The nitrous acid, however, diſſolves it with great rapidity, and during the ſolution copiouſly emits denſe red vapours. This is one of thoſe ſolutions from which the calx is moſt eaſily ſeparated by water. On being dropped into water a bright powder is depoſited, called magiſtery of biſmuth. This is ſuppoſed to be the ſame with the ſubſtance called *pearl white*, well known as a coſmetic; for when rubbed on the ſkin it gives it a white ſhining colour. But in reality all theſe metallic ſubſtances ultimately darken the ſkin, for a calx when long expoſed to the air, and the exhalations of animal bodies, parts with its oxygen to the inflammable matter, and aſſumes a dark colour. Biſmuth, moreover, poſſeſſes many properties in common with lead, and there are ſome inſtances in which the external uſe of this metal has produced the worſt effects.

Solutions of biſmuth are particularly affected by fetid odours, which proceed from putrefying ſubſtances. This ſeems chiefly to depend on the ſulphureous particles which are exhaled in thoſe proceſſes, and is illuſtrated by a ſtriking experiment. If characters are written with a ſolution of biſmuth on the firſt page of a book of fifty leaves, and the laſt page is impregnated with a ſmall quantity of the liquid liver of ſulphur, a ſhort time afterwards the hepatic vapour, carried by the air which circulates between all the leaves, arrives at the other extremity of the book, and converts the colourleſs characters marked on the firſt page into a deep brown. It is affirmed that the hepatic gas paſſes through the paper; but it is ſufficiently proved that the air carries the gas in this manner from one leaf to another, ſince the effect does not take place when the leaves are glued together. This experiment evinces in the cleareſt manner the impermanency of the beautifying effect of the calces of biſmuth.

The nitrous ſolution of biſmuth is without colour, and when well ſaturated affords cryſtals without evaporation. But by evaporation and cooling theſe cryſtals may always be obtained. The nitre of biſmuth detonates feebly, and with reddiſh ſcintillations;

tions; after which it melts and inflates, leaving a calx of a greeniſh yellow colour. This ſalt expoſed to the air loſes its tranſparency, at the ſame time that the water of cryſtallization is diſſipated.

The acetous acid diſſolves biſmuth ſlowly, and in ſmall quantities.

Inflammable gas alters the colour of biſmuth, and gives it a violet tinge. Sulphur unites with biſmuth, eſpecially with its calx; in which ſtate it reſembles crude antimony. It unites with all the metals, except zinc and regulus of cobalt, and takes away their malleability and ductility, and increaſes their diſpoſition to calcine; it alſo increaſes their fuſibility, hence its uſe in ſoldering lead and tin. If added to a mixture of lead and tin, in certain proportions, it produces a metallic compound, which retains the ſtate of fluidity in the heat of boiling water.

Biſmuth is chiefly uſeful for mixing with tin to produce pewter, rendering it harder, and better to be caſt into molds. It is alſo uſed in making printers' types; for by giving a greater tenuity to the fuſed maſs, it fits it for receiving a neater impreſſion. An amalgam for foiling glaſs globules is made of ten parts of mercury, two of biſmuth, and one of lead and tin. It may be ſubſtituted inſtead of lead in the art of cupelling the perfect metals, becauſe, like that metal, it has the property of flowing into a glaſs which is abſorbed by the cupels.

Biſmuth is often found native. It is alſo found united with arſenic, ſulphur, iron, and ſometimes in a calciform ſtate. The ſulphureous ore of biſmuth is of a whitiſh grey, inclining to blue; it has the brilliancy and colour of lead ore or galena, and almoſt always exhibits ſquare facets, but it is never found in fragments truly cubical. It is very rare, and is found at Baſtnas, in Sweden, and at Schneeburg, in Saxony.

CHAP. XXV.

ANTIMONY.

Natural Hiſtory of Antimony.—Regulus.—Snow of Antimony.—Calcination of Antimony.—Combinations with Acids.—Butter of Antimony.—Antimonial Wine.—Uſes of Antimony in Medicine.—Flores Antimonii.—Glaſs of Antimony.—Crocus of Antimony. Sulphur of Antimony.—Tartar Emetic.—James's Powder.

THE ſubſtance, which is commonly known by the name of antimony, is a combination of that metal with ſulphur. This mineral is of a blackiſh grey, in brittle plates or needles, of various magnitudes, joined together in different forms. It is ſometimes mixed with other metals, particularly lead and iron, and is very common in Hungary, and in ſome of the provinces of France. From this ore the regulus of antimony is ſeparated by fuſion. The antimony then forms a maſs of metal at the bottom of the veſſel, while the other matter becomes a ſcoria above it.

The appearance of antimony is bright, approaching, when very fine, to that of ſilver. It is very brittle, and it is compoſed of oblong plates or laminæ. When melted it forms a ſmooth maſs like other metals, but upon breaking it, we find the plated appearance on the inſide. The plated appearance depends on the cryſtallization, which begins at the part that firſt congeals. The regulus of antimony, which is prepared for commercial purpoſes,

poſes, is caſt into flat and circular pieces, which have a cryſtallization on their ſurface, in the form of the leaves of fern.

In fuſibility antimony holds a middle rank, requiring a perceptible degree of red heat before it becomes fluid. In the ſame degree it emits vapours copiouſly if freſh air is admitted, which always promotes the volatility of metals. If theſe fumes are condenſed, they form a white powder. In particular circumſtances they cryſtallize. They are, indeed, a perfect metallic calx, to which the names of argentine, and ſnow of antimony, have been applied. This ſubſtance is ſo highly charged with the oxygenous principle, as to be ſoluble in water, and to approach to the nature of an acid.

To calcine antimony by heat and air alone, let the metal be powdered, then lay it on a broad ſhallow veſſel, and apply heat not ſufficient to convert it into fumes. This operation cannot be well performed, unleſs the antimony is in a ſtate of minute diviſion, ſo as to preſent a large ſurface to the air. The proceſs muſt be conducted with caution at the beginning, on account of the fuſibility of this compound of ſulphur and antimony; but in proportion as the ſulphur is diſſipated, the remainder becomes more refractory, and the fire may be raiſed to ſuch a degree as to make the veſſel in which the antimony is contained red hot. The ſurface of the metal becomes at firſt tarniſhed, and ſoon afterwards it is changed into an earthy powder of a duſky colour, which, by continuance of the proceſs, becomes white. Theſe calces have a different degree of friſibility according to the degree of calcination. When little calcined a ſtrong heat converts them into a glaſs of an opake or black colour. When further calcined more heat is required, and the glaſs is a deep yellow. When calcined to whiteneſs, the moſt violent heat will not melt them without the addition of borax, and the maſs is then of a pale yellow. Here we obſerve the effect of the preſence of oxygen in rendering this calx leſs fuſible, and depriving it of colour. Theſe calces may be reduced, but moſt readily when little calcined, by adding an equal quantity of black flux, or one-fourth of charcoal or ſoap.

The foſſil fixed alkali brings antimony neareſt to the ſtate of the perfect metals. For this diſcovery we are indebted to Margraff, who melted two ounces of regulus of antimony with one of foſſil alkali. He repeated the fuſion eight times, and every time he uſed freſh alkali; but the three or four laſt times he did not uſe quite an ounce of alkali, but made uſe of a mixture of alkali and flint. Every time it was thus melted the regulus loſt ſome of its weight, and the alkali, having diſſolved part of it, was tinged green. The remaining metal was always whiter and brighter, and acquired a ſmall degree of toughneſs. The texture was much finer than before, and it would eaſily amalgamiſe with mercury. The weight of the regulus was reduced to about one half by eight operations. With the vegetable fixed alkali the effect was ſimilar, but not ſo remarkable.

The regulus of antimony is calcined with great rapidity by the nitrous acid, but the muriatic and vitriolic ſcarcely act on it, unleſs aſſiſted by heat. By the union of antimony with all theſe acids, ſaline compounds are produced, which are deliqueſcent, and which are decompoſed by water, or the ſimple application of heat. The oxygenated muriatic acid and aqua regia diſſolve the regulus of antimony with great facility.

But beſides theſe methods of aſſiſting the action of the muriatic acid on antimony, there is another proceſs for combining the muriatic acid with the regulus. A quantity of mercurial ſublimate in powder being mixed with the regulus of antimony, the acid acts upon the antimony immediately, ſo as to render the mixing of them dangerous, from the corroſive fumes which ariſe. The common way is to powder them and mix them, and heat being applied, the muriatic acid of the ſublimate attracts the antimony, and riſes with it in the form of a very volatile compound, which condenſes in the neck of the retort, of a conſiſtence between ſolid and fluid, and is hence called butter of antimony. It is very cauſtic, and is uſed to conſume the callous lips of ulcers, but is too violent to be uſed internally. If it is ſubjected to a ſecond operation, it comes over fluid. The ſame proceſs is employed to combine other metals with the muriatic acid. When butter of antimony is thrown into pure water, an abundant white precipitate or calx falls down, which is a violent emetic, and is known by the name of powder of algaroth.

The vegetable acids alſo act upon antimony weakly when applied to it in its metallic ſtate, but much more ſtrongly when it is ſlightly calcined. A ſolution of this kind was formerly uſed under the name of antimonial wine. A quantity of the regulus was caſt in the form of a cup, which was occaſionally filled with wine, and having ſtood a day or two, it became emetic. The quantity of antimony diſſolved was very ſmall, but was diſcoverable on adding an alkali, and precipitating it.

To give crude antimony any action as a medicine, it is neceſſary to deſtroy a part of the ſulphur, and alſo in ſome meaſure to calcine it. The more ſulphur it retains, the leſs active it is. If we calcine it too much we alſo deſtroy its effects; for in the ſtate of a white calx it has little or no medical efficacy. The flores antimonii is a preparation in which the antimony is nearly deprived of ſulphur, and at the ſame time furniſhed with ſome oxygen. It is very violent in its effects; a very minute quantity producing convulſions and vomiting. Antimony indeed may be reduced to ſuch a ſtate as to affect the body in ſmaller quantities even than arſenic.

When antimony is combined with ſulphur, and urged with a ſtrong heat, it aſſumes the appearance of glaſs. The glaſs of antimony, though not much employed as a medicine, is very uſeful as a preliminary to the moſt valuable preparations. Few of the metals, indeed, have ſo much attracted the attention of chemiſts as antimony, and its preparations have been accordingly very numerous.

rous. To avoid, therefore, unneceſſary prolixity, it will be proper to confine the reader's attention to thoſe which have been found moſt uſeful.

By deflagrating antimony with nitre, the metal is calcined, as well as when expoſed to heat in contact with air. The antimonium calcinatum of the London Pharmacopœia is prepared by throwing a mixture of eight ounces of antimony, with two pounds of nitre, into a crucible heated to a white heat. The white matter is burnt for half an hour, and, when cold, is powdered and waſhed with diſtilled water. This preparation is ſo inert, that it has been doubted whether it is capable of any action whatever on the human body.

When the antimony and nitre are in equal quantities, they form a more active compoſition. The mixture burns with violence, and ought to be injected, in ſmall quantities at a time, into the heated crucible. After the combuſtion there remains a mixed matter, partly of a dark red, and partly whitiſh. Upon melting, it ſeparates into a heavier part of a deep red, and a ſaline part above of a paler colour. The former is the object of the operation, and is called crocus of antimony. The College direct a ſmall quantity of ſea ſalt to be uſed in this preparation, which promotes fuſion, and probably increaſes the activity of the compoſition.

Fixed alkalies have a great degree of activity with crude antimony, on account of their attraction for the ſulphur. The eaſieſt mode of combining them is fuſion. The firſt effect of the alkali is to combine with the ſulphur, and form a liver of ſulphur, which by a continuance of heat ſeems to diſſolve the regulus of antimony. This compound is readily diſſolved by boiling water, and if we add to the ſolution an acid, the metallic matter and ſulphur are depoſited of a yellow colour. This ſubſtance, however, which is called ſulphur antimonii præcipitatum, may be obtained in an eaſier manner, by boiling crude antimony in a ſolution of alkali, and then precipitating the ſulphurated antimony with the vitriolic acid.

The antimonium tartariſatum, or *tartar emetic*, may be obtained either by the uſe of the crocus or the glaſs of antimony. The former is, however, preferred by the London College, who adopt the following proceſs: Take of crocus of antimony powdered one pound and an half, cryſtals of tartar two pounds, diſtilled water two gallons. Boil them in a glaſs veſſel about a quarter of an hour; filter the liquor through paper, and ſet it by to cryſtallize. Tartar emetic conſiſts of the acid of tartar united to vegetable alkali and antimony partially calcined.

The pulvis antimonialis of the pharmacopœia, which is thought to be nearly the ſame as James's powders, is prepared by expoſing equal parts of antimony and hartſhorn ſhavings to a moderate heat, with a free acceſs of air. With reſpect to the peculiar merits of James's powders, they have never been proved either in theory or practice. The circumſtances upon which the effects of antimonial preparations depend are well known, and though we cannot with certainty aſcertain the proceſs of Dr. James, there is no reaſon to think that it is preferable to that of the pharmacopœia, in the preparation of the pulvis antimonialis. The love of myſtery, however, has always had an influence over mankind, and there is no reaſon to believe that the period for its ceſſation is at hand.

The regulus of antimony is employed in the manufacture of printers types, and in making ſhot.

CHAP. XXVI.

ZINC.

General Deſcription of this Metal.—Philoſopher's Wool.—Union with Acids.—White Vitriol.—Detonation of Zinc with Nitre.—Combination with Metals.—Pewter.—Its Uſe in Fire-works.—Natural Hiſtory of Zinc.—Calamine.—Black Jack.—Braſs, how made.—Tutty.—Pinchbeck.

THIS metal is in ſome degree malleable, and therefore holds a middle place between the ſemi-metals and metals, though it is uſually referred to the former diviſion. Its appearance is blue and brilliant, and when broken it is found to be cryſtallized in narrow plates. It melts when red hot; if heated in cloſe veſſels to a vivid red or white heat, the whole of it riſes in vapour, and may again be condenſed without any change. When heated, however, in contact with air, it burns rapidly with a white flame and crackling noiſe, and is converted into a white, ſoft, and flocculent ſubſtance, called flowers of zinc, or lana philoſophorum. If the zinc is burnt in a deep crucible, this calx attaches itſelf to the upper part of it, though ſome part is always loſt even in the deepeſt veſſel, which will admit the air with ſufficient freedom to maintain the combuſtion. If a gentle heat is applied no light is produced, and the ſurface of the zinc becomes gradually covered by a grey calx, which changes to white, by being afterwards heated in contact with air. Zinc is ſo apt to undergo this change that it is difficult to melt ſmall pieces of it into a maſs, for in the moment after they arrive at the melting point they are covered with a ſkin, which prevents their union. The calx of zinc is not very eaſily reduced to a reguline ſtate, as the heat neceſſary for this effect is apt to volatilize the metallic product.

Zinc is readily acted on by all the acids, and no metal ſhews a greater attraction for them. It produces with them metallic ſalts, in which the acid is more neutralized than in the other metallic compounds of the ſame deſcription. The acids do not depoſit the zinc when they are diluted with water.

The concentrated vitriolic acid does not act on zinc, unleſs aſſiſted by heat, and it then gives out ſulphureous fumes. It is diſſolved, however, with rapidity, and without the aſſiſtance of heat, by the ſame acid in a diluted ſtate, and this proceſs is attended with the copious production of hydrogen gas, which indicates the decompoſition of the water. From this ſolution may be obtained white vitriol, which, as well as the flowers of zinc, is employed in medicine.

The diluted nitrous acid acts on zinc with ſingular violence, and nitrous gas is ſo copiouſly diſengaged, that the mixture ſometimes exhibits the appearance of boiling. The ſolution is very cauſtic, and affords cryſtals by evaporation and cooling, which ſlightly detonate on hot coals, and leave a calx behind. This ſalt is deliqueſcent. The diluted muriatic acid acts on zinc with the ſame production of hydrogen gas as the vitriolic; but this ſolution does not afford cryſtals.

The vegetable acids acquire from zinc a ſweetiſh taſte and ſtipticity. The action of the fluoric and boracic acids on zinc are not known. Water, impregnated with carbonic acid, diſſolves a conſiderable proportion of zinc.

All the ſolutions of zinc in acids are precipitated by lime, magneſia, the fixed and volatile alkalis; the latter re-diſſolves the precipitate if it is added in exceſs.

Zinc has the property of decompoſing ſeveral neutral ſalts. If it is conſiderably heated with vitriolated tartar in a crucible, it decompoſes the ſalt, and forms a liver of ſulphur, in the ſame manner as the regulus of antimony does. In this experiment the metal ſeizes the oxygen of the vitriolic acid, and the acid paſſes into the ſtate of ſulphur, which the alkali diſſolves. The hepar formed by this combination diſſolves a portion of the calx of zinc. All the vitriols are likewiſe decompoſed by zinc.

When pulverized zinc is added to fuſed nitre, or projected together with that ſalt into a heated crucible, a very violent detonation takes place. The activity of the inflammation is ſuch, that portions of burning matter are thrown to a diſtance out of the crucible, in ſuch a manner as to require precaution on the part of the operator. Only ſmall quantities of the mixture ſhould be caſt into the crucible at once. The zinc burns by the aſſiſtance of the oxygenous gas afforded by the nitre, and is afterwards found in a calciform ſtate, more or leſs perfect, according to the proportion of nitre uſed. Part of the calx combines with the alkali, and forms a compound ſoluble in water.

Zinc decompoſes common ſalt, and alſo ſal ammoniac, by ſeizing the marine acid. The filings of zinc alſo decompoſe alum when boiled in a ſolution of that ſalt.

The relation of zinc to ſulphur is remarkable, as it is the only metal which does not unite with it in a reguline ſtate. M. Morveau, however, has diſcovered, that the calx of zinc unites eaſily with ſulphur by fuſion.

The regulus of zinc is capable of being united with that of arſenic, but it more readily unites with arſenic in its calciform ſtate. Zinc diſtilled with white arſenic deprived it of part of its oxygen, and was converted into a calx, while a correſponding quantity of arſenic was reduced to a regulus.

Zinc does not combine with biſmuth, and when theſe two metals are fuſed together, the biſmuth takes the lower place on account of its greater gravity, and may be ſeparated by a ſtroke of the hammer. It will not unite with nickel. Its volatility renders it extremely difficult to combine it with metals which are of difficult fuſion, as iron and copper. It is, however, united to ſeveral metals for particular purpoſes in the arts. It is added in ſmall quantities to tin, or to a mixture of tin and lead, in the compoſition of pewter, which it improves both in adding to the whiteneſs and brilliancy, and increaſing the hardneſs. It is employed in many alloys, particularly in tombac, prince's metal, and the various kinds of braſs. Fine filings of zinc are uſed to produce brilliant ſparks in fire-works. Some perſons have propoſed to ſubſtitute zinc for tin in lining copper veſſels; the latter metal, in conjunction with lead, having been ſuppoſed inſufficient to prevent the dangerous effects of the lead. Macquer allows that this metal ſpreads more evenly on the copper, is much harder, and leſs fuſible, than the lining of tin, but objects to it, becauſe it is ſoluble in vegetable acids, and has a conſiderable emetic power. Mr. De la Plance, however, has taken the ſalts of zinc, formed by the vegetable acids, in greater quantities than they can be contained in aliments which have been dreſſed in veſſels lined with zinc, without experiencing any dangerous effect. Experiments are yet wanting to prove the ſuperiority of zinc lining over that of tin.

Zinc is found in the following ſtates: It is ſometimes, though rarely, diſcovered native in flexible, greyiſh, and inflammable fibres. Zinc in its ore is generally in the form of a calx; when the ore contains no other metal but zinc it is never in any other form, but it is often mixed with other ores, which contain ſulphur and arſenic, and theſe muſt be evaporated by roaſting. The richeſt ores are compact and ponderous, and are called lapis calaminaris, or calamine, they are found in the pariſh of Holywell, in Flintſhire.

Margraff has aſcertained the quantity of zinc contained in different ſorts of calamine:

	Parts.		Parts.	
Calamine, from near Cracow	16	gave	2½	zinc.
Calamine, from England	16	——	3	——
—— from Breſlaw	16	——	4½	——
—— from Hungary	16	——	2½	——
—— from Holywell	16	——	7	——

In one hundred parts of lapis calaminaris were found eighty-four of calcined zinc, three of calcined iron, about one of pure clay, and twelve of ſiliceous earth, according to Bergman.

There is another ſpecies of mineral uſed in making braſs called blende, mock lead, or black jack, which conſiſts of zinc mineralized by ſulphur, and ſometimes by iron.

The method of making ordinary braſs is as follows: —Copper in thin plates, or, which is better, copper reduced (by being poured when melted into water) into grains of the ſize of large ſhot is mixed with calamine and charcoal, both in powder, and expoſed in a melting pot for ſeveral hours to a fire not quite ſtrong enough to melt the copper, but ſufficient to reduce the zinc, and convert it into vapours. Theſe vapours penetrate the copper in proportion to the ſurface expoſed to their action, changing its colour from red to yellow, and augmenting its weight in a great proportion. When they make braſs, which is to be caſt into plates, from which pans and kettles are to be made, and wire is to be drawn, they uſe calamine of the fineſt ſort and in greater proportion than in the compoſition of common braſs.

Tutty is the flowers of zinc taken from the furnaces in which the ores containing this metal are wrought. It varies in colour and conſiſtence according as the calx is more or leſs perfect, and is mixed with more or leſs of an argillaceous ſubſtance. Newman ſays, that the lapis tutiæ is compoſed of clay beaten up with a ſmall quantity of lapis calaminaris.

Zinc and copper, when melted together in different proportions, conſtitute what are called pinchbeck, &c. of different ſhades of yellow. Margraff melted pure zinc and pure copper together in a great variety of proportions, and he found that eleven, or even twelve parts of copper, being melted with one of zinc, gave a moſt beautiful and very malleable tombac or pinchbeck.

CHAP. XXVII.

IRON.

Extenſive Utility of this Metal.—Its Properties.—Natural Hiſtory of Iron.—Eagle-Stones.—Blood-Stones.—The Loadſtone.—Emery.—Ochres.—Smelting of Iron.—Forging of Iron.—Making of Steel.—Tempering of Steel.—Caſt Steel.—Great Diſpoſition in Iron to unite with other Bodies.—Green Vitriol, how procured.—Pruſſian Blue.—Ink.—Inflammation of Sulphur and Iron.—Tinning of Iron.—Preparations of Iron uſed in Medicine.

OF all metals, and I might perhaps be juſtified in adding, of all mineral ſubſtances, the moſt generally uſeful is iron. To ſpecify its uſes would be to produce a catalogue of every thing that contributes to the ſuſtenance and the convenience of life. By the aſſiſtance of this metal we till the land, and obtain the fruits of the earth in greater abundance and perfection than we could by any other means; by its agency we are enabled to penetrate the earth itſelf, and procure whatever it contains that may be uſeful or ornamental to man; there is ſcarcely a mechanical trade, which could be conducted on the preſent principles without its aid, and many of them could not even exiſt were we deprived of it: even in domeſtic life our ſafety, our comfort, and our pleaſure, all ſeem in ſome meaſure to depend on this moſt valuable production of the earth. As the quantity of this, as well as of ſome other minerals, which appear almoſt neceſſary to ſocial exiſtence, muſt be limited, I have often thought that the want of a ſufficient ſupply, which, on the ſuppoſition of the preſent ſyſtem of things being continued for ever, muſt at ſome time neceſſarily take place, forms a forcible argument againſt the abſurd and ignorant hypotheſis of the eternity of the world.

The external appearance of this metal is well known, and its hardneſs and elaſticity are ſeen in the various inſtruments and utenſils which are formed of it.

It is the moſt ſonorous of all the metals, except copper; but in ſpecific gravity it is inferior to moſt of them, being only about ſeven times and a half the weight of water. Iron has a conſiderable ſmell, eſpecially when rubbed or heated. It likewiſe has a very perceptible ſtyptic taſte.

Iron is very ductile, and may be drawn into wire as fine as a human hair; and it is ſo tenacious, that an iron wire of one tenth of an inch diameter will ſupport a weight of fifteen hundred pounds. Iron may be ignited, or at leaſt made ſufficiently hot to ſet fire to brimſtone, by a quick ſucceſſion of blows with a hammer; but it requires a moſt intenſe heat to fuſe it, on which account it is brought into ſhape by hammering while it is in a heated ſtate. Iron is alſo poſſeſſed of another property, which ſupplies in a great meaſure the purpoſes of fuſion. When pieces of common ſoft iron are heated to a certain degree, and are ſuddenly taken out of the furnace and expoſed to the air, we obſerve their ſurface covered over with an appearance of varniſh, which proceeds from the ſurface of the metal being partly fuſed. If two pieces of iron in this ſtate are ſtruck together, they unite very firmly, and this proceſs is called welding. It is diſtinguiſhed from all other metals by being attracted by the loadſtone. Another property, which diſtinguiſhes iron from all other metals, is that of ſtriking fire with flint. This phenomenon depends on the actual inflammation of ſmall particles of the metal, which preſent a large ſurface to the action of the air, and which are heated by the friction which ſeparates them from the maſs, ſo as to diſpoſe them to inflammation. Theſe particles are ſeldom larger than the two hundredth part of an inch in diameter, and when examined by a magnifier, are found to be brittle, of a greyiſh colour, reſembling the ſcales of burnt iron. Another proof of the inflammability of iron is, that iron wire, heated at one end, and plunged in a jar of oxygen gas, burns with conſiderable rapidity, and with a very brilliant flame.

Iron is by far the moſt abundant in nature of all the metals. It is not only contained in almoſt every foſſil, particularly in thoſe which are coloured, but makes a part of vegetable and animal matter. With reſpect to the ores of iron, however, as they are very numerous, it will be neceſſary only to notice thoſe from which the metal may be extracted with advantage. In theſe ores iron exiſts either in the metallic or calciform ſtate, or mineralized by different ſubſtances.

Native iron is known by its colour and malleability. It is very rare, and is only found occaſionally in iron mines. Some naturaliſts think that theſe apparently native ſpecimens of iron have been produced by art, and have been buried in the earth by accident.

In the Philoſophical Tranſactions for the year 1788, vol. lxxviii. is an account of a maſs of native iron, weighing by admeaſurement about three hundred quintals, which lies in the midſt of a wide extended plain, in the middle of South America, in latitude 70° 28′ ſouth, and at the diſtance of ſeventy leagues eaſt, one quarter ſouth, from the hamlet of Rio Salado. It has the appearance of having been liquid, and bears the impreſſion of human feet and hands of a large ſize, as well as of the feet of large birds common in that country. The extraordinary fact of ſuch a maſs of iron being found in the center of a vaſt tract of level land, where there are no mountains, nor even the ſmalleſt ſtone, within a conſiderable diſtance, projecting above the ſurface of the earth, is referred by the writer of this article to an ancient volcanic exploſion, of which there are ſome veſtiges near it. The ſame ſuppoſition is urged with equal probability to account for the production of another maſs of native iron, in the ſhape of a tree with its branches, which the author aſſerts, on indubitable authority, is known to exiſt in theſe immenſe foreſts. Some ſpecimens of the iron were preſented to the Royal Society, who afterwards depoſited them in the Britiſh Muſeum. That large maſſes of iron were really obſerved in theſe ſituations there is no reaſon to doubt, but I ſhould rather attribute the ſuppoſed impreſſions to accidental reſemblances.

The largeſt quantities of iron ores are in a calciform ſtate, as in ochres, bog ores, &c. which are diſpoſed in ſtrata, in the manner of ſtones. The ætites, or eagle ſtones, are a variety of the bog ores; they are in different forms, commonly oval or polygonous, compoſed of concentric layers diſpoſed round a nucleus, which is frequently moveable in the centre of the ſtone. The hæmatites, or blood ſtones, are named from their colour, which is commonly red. The loadſtone is a dull iron ore, the varieties of which are diſtinguiſhed by their colour.

Emery is a grey or reddiſh iron ore; it is very hard and refractory, and is found in abundance in the iſlands of Guernſey and Jerſey. It is reduced into powder in mills, and in this ſtate is uſed to poliſh glaſs and metals. Spathoſe iron ore is a calx of iron combined with cretaceous acid; it is uſually of a white colour. Nature likewiſe preſents iron in a ſaline ſtate, united to the vitriolic acid, and forming green vitriol. This ſalt is particularly found in mines which contain pyrites. Iron is often found united to ſulphur, and then forms what are called martial pyrites. This metal is alſo found combined with arſenic, both being in the metallic ſtate. There is alſo a black iron ore, which is in ſome meaſure attracted by the magnet. Iron is ſometimes found in the form of a blue powder. In this ſtate it is called native pruſſian blue. It is mixed with vegetable earths, and eſpecially with turf. It was diſcovered ſome years ago, that iron is often united with the phoſphoric acid. The muddy or bog ores are ſometimes of this nature.

The ores of iron do not afford the metal unleſs urged by a great heat. Some ores are melted without addition; but it is neceſſary to aſſiſt the fuſion of others by calcareous matters. The limeſtones, the iron ore, and charcoal, are alternately thrown into the furnace, and the whole is covered with a layer of charcoal. The melted ore is reduced by the contact of the coaly matter, and is then ſuffered to run into a cavity uſually formed in ſand. The metal in this ſtate is called crude or caſt iron. A vitreous matter, called ſlag, paſſes after the iron, and conſiſts of the ſtones which were added to facilitate the fuſion. The metal thus obtained has not the leaſt ductility; but it is deemed better in proportion as its colour is darker.

The caſt iron is carried to be refined in a forge furnace, with a hollow hearth, in which it is ſurrounded with charcoal, where the fire is urged by bellows till the metal begins to ſoften. When it is in this ſtate, it is repeatedly ſtirred, in order that it may preſent a larger ſurface to the air. By the action of the heat and air it emits ſparks, which proceed from the conſumption of a quantity of plumbago, or black lead, which is contained in the crude iron, and which it is commonly ſuppoſed to acquire from the fuel during the proceſs of ſmelting*.

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* It conſiſts of carbon, with about one tenth of its weight of iron.

The iron, by this mode of refining, loſes, beſides the plumbago, a quantity of ſiderite, which Bergman ſuppoſed to be a peculiar metal, but which is now found to be a combination of iron and phoſphoric acid.

After the iron has been kept in this ſituation a certain time, it is carried to a large hammer, generally moved by water, where it is formed into bars. The hammering, by bringing the particles of the iron nearer together, preſſes out the impurities, and thus completes what was left deficient by the fuſion. This heating and hammering are repeated a number of times, till the iron has acquired the deſired degree of perfection. Crude iron loſes from a quarter to a third of its weight by the proceſs of refining, and is then called forged iron.

Steel is made by ſurrounding the bars of iron with a compoſition of which charcoal is the chief and only eſſential ingredient, and by keeping them in an intenſe heat a longer or ſhorter time, according to their thickneſs. They are then taken from the furnace, and plunged in cold water. The metal is now found to be more fuſible than it was before, but to have leſs ductility and ſoftneſs. Its texture is finer; it breaks ſhort; its fracture is always grey, and it has gained a ſmall increaſe of weight.

With reſpect to the chemical ſtates of the metal, in the three forms of caſt iron, forged iron, and ſteel, it appears that they chiefly depend on the quantities of plumbago. By ſolution in acids, it is found that caſt iron contains a large quantity of plumbago, that ſteel contains ſome of it, but that the moſt malleable forged iron contains ſcarcely any; it therefore appears, that ſteel is in an intermediate condition between caſt iron and forged iron, and that, in making the former into the latter, the metal muſt paſs through the ſtate of ſteel. In ſome foreign works they actually manufacture ſteel by only ſtopping the proceſs of refining at a certain point. In theſe manufactories, however, they make uſe of an ore of uncommon purity; and the ſame proceſs does not ſucceed with ordinary ores, becauſe the metal obtained from theſe contains other impurities beſides plumbago, which cannot be ſeparated without reducing the iron to its malleable ſtate.

There are differences in the working of iron, according to the ores from which it is obtained, the cauſes of all of which have not been diſcovered. The preſence of phoſphoric acid, however, is known to produce a brittleneſs in iron when cold, which occaſions that ſort of iron to be called *cold ſhort* iron by the workmen. Phoſphoric acid is chiefly found in iron obtained from bog ores.

The workmen employed in tempering ſteel judge, by the different colours it aſſumes during the operation, of the degree of hardneſs it has acquired. That theſe colours may be obſerved, ſome part of the metal to be tempered ſhould be ſmooth.

The changes of colour depend on the calcination of the iron; for if the contact of air is prevented by the thinneſt covering of any oily matter, the effect is entirely prevented. The colour is firſt a pale yellow; if a piece of ſteel is then ſtruck off, it will be very hard. If the ſteel is left in the fire for a longer time, it acquires a deeper yellow and more toughneſs, with ſcarcely any diminution in the degree of hardneſs; when brought down to the colour of watch ſprings, it is of the fitteſt temper for cutting wood. Steel, by being heated in this manner, becomes ſucceſſively white, yellow, orange, red, violet, and laſtly blue, which colour remains a conſiderable time; but if the heat is raiſed it becomes whitiſh.

Steel, ſtrongly heated while in the fire, aſſumes a red and ſparkling appearance, it next becomes very white and dazzling, and then burns with a ſenſible flame.

Caſt ſteel is nothing more than ſteel refined by fuſion. During this proceſs it throws up ſcoria, whilſt the metallic matter which remains is much harder than before, and its texture more uniform.

Iron is one of the metals which is acted on moſt powerfully by acids. But not only acids, but all ſaline ſubſtances ſeem to affect it, and even water is capable of acting on it ſo as to acquire from it a peculiar taſte. The tendency, indeed, which this metal has to combination with other bodies, particularly with oxygen, which occaſions ruſt, renders it incapable of permanency, and for this defect no ſufficient preventative has yet been diſcovered.

M. Lavoiſier, having expoſed iron with water in a glaſs veſſel over mercury, obſerved that the iron became ruſty, and that the water was diminiſhed in quantity. The iron was increaſed in weight, and there was a production of inflammable gas, ſo that in this experiment the water was decompoſed by the iron, even without the preſence of air.

Iron is acted on by the vitriolic, muriatic, and nitrous acids, with nearly the ſame phenomena as zinc. The products, however, are very different. The ſolution of iron in the vitriolic acid is of a green colour, and by evaporation produces the green cryſtals, well known under the names of ſal martis, green vitriol, and copperas. The green vitriol uſed in commerce is obtained in the following manner: Pyrites, which are natural combinations of iron and ſulphur, are expoſed to the action of the air and rain in ſhallow pits lined with clay. After having been in this ſituation a week or a fortnight they grow hot and crumble down, and when carefully examined are found to contain ſmall cryſtals. Theſe are diſſolved by the rain, and conveyed by pipes into a reſervoir in a houſe, whence the liquor is pumped into a boiler made of lead. This liquor is found to have an exceſs of acid, which is remedied by caſting pieces of iron into it when heated ſo as to ſimmer. By the addition of the iron a quantity of the earth of alum is alſo depoſited. As the liquor cools, the greater part of the ſal martis is depoſited. By the expoſure of the pyrites to the action of air and water, the ſulphur attracts the oxygenous principle, and is thus converted into vitriolic acid. Sal martis is liable to the watery fuſion; when expoſed to a ſtrong heat the acid begins to exhale, and as it exhales the natural colours of the calx of iron appear. It is firſt yellow, then orange, then red; if it is calcined to a greater degree, ſcarcely any of the acid is left, and the calx remains of a deep purple colour, and is known under the name of colcothar of vitriol. The nitrous acid acts with ſo much violence on iron as to convert it into a brown calx. With the muriatic acid iron affords cryſtals of a livelier green colour than copperas, which will not, like copperas, part with the acid by the application of heat.

All ſolutions of iron, if expoſed to the air, depoſit part of the metal in the form of a calx. Alkaline ſalts precipitate the metal of a bluiſh grey colour, if the ſolution is freſh, but if long kept, in the form of a yellow powder. Mild vegetable alkali ſeparates a yellow calx from the ſolution of iron in the nitrous acid, which ſoon becomes of a beautiful red orange colour. If the mixture is agitated during the efferveſcence, the precipitate is re-diſſolved in much greater quantity than by the pure vegetable alkali. This ſolution is known by the name of Stahl's martial alkaline tincture.

But the moſt remarkable precipitation is that produced by a fixed alkali prepared with animal inflammable matter. The alkali is treated by mixing it, when dry, with twice its weight of blood, which has been indurated and reduced to powder; the mixture is put into a crucible, and a gentle heat applied; particular care muſt be taken to uſe the due degree of heat, which is known by the diſappearance of a blue flame and ſmoke, which is at firſt obſervable on the ſurface. The matter thus prepared, being infuſed in water, affords an alkaline ſolution, which precipitates iron of a deep blue colour,

lour, eſpecially if a little muriatic acid is added. The eſſential ingredients of the matter obtained by the above proceſs ſeem to be a peculiar matter called pruſſic acid, and an alkali. The baſe of the pruſſic acid, according to M. Berthollet, conſiſts of carbon, hydrogen, and azote. When the alkali, combined with this peculiar acid, is added to a ſolution of iron, the alkali takes the acid from the iron, while the pruſſic acid unites with the metal and falls to the bottom in the form of a blue powder. This effect of the alkali, thus prepared, is the foundation of the proceſs for obtaining that valuable pigment, known by the name of Pruſſian blue.

Another ſingular, and not leſs uſeful circumſtance, in the hiſtory of iron is the effect produced on it by aſtringent vegetable ſubſtances. The principle of aſtringency, which is now found to be a peculiar acid, called, in the new nomenclature, gallic acid, reſides in a great number of vegetable matters, particularly oak galls, tea, &c. According to M. de la Metherie, however, the acid of galls is only a variety of the colouring principle. Galls are protuberances on the leaves of the oak, occaſioned by the puncture of a particular inſect Any of theſe ſubſtances, added to a ſolution of green vitriol, precipitates a fine black fecula, which may be ſuſpended a conſiderable time in the fluid by the addition of gum arabic. Oak galls are commonly made uſe of in this proceſs, which is that of making ink. The following proportions of theſe ingredients for making ink anſwer very well. One ounce of martial vitriol to three of powdered galls; to which one ounce of powdered logwood may be added, to render the ink more permanent, and one ounce of gum arabic to ſuſpend the colouring matter. Let theſe be infuſed in a quart of water or vinegar for ten days, and ſhaken occaſionally, when the ink will be fit for uſe.

The colouring matter of ink ſeems to be produced from an union of the acid of the galls with ſome part of the iron in a calciform ſtate. A ſmall quantity of any of the mineral acids deſtroys the colour of the ink, by diſſolving the iron, which was imperfectly precipitated; and this colour is again reſtored by the addition of an alkali, which takes away the acid. The black fecula of ink is not magnetical; but it may be converted into a brown magnetic calx by heat. Ink becomes blacker by expoſure to the air, which acidifies more completely the principle combined with the iron; but ancient writings become more and more yellow in conſequence of the decay of the vegetable matter. Their legibility may be reſtored by the uſe of infuſion of galls, or gallic acid. The beſt method, however, of reſtoring the legibility of ancient writings, conſiſts in ſpreading a ſolution of the Pruſſian alkali thinly with a feather over the traces of the letters, and then to touch it gently, and as nearly upon or over the letters as can be done, with a diluted acid, by means of a pointed ſtick.

The only eſſential ingredients of ink are green vitriol, galls, and water. Dr. Lewis has made many uſeful experiments on the proportions of theſe ingredients which produce the beſt ink. He found that equal quantities of galls and green vitriol produced the deepeſt colour, but not the moſt durable; he found, that by increaſing the quantity of the galls the colour was rendered more durable; that with three times the weight of the galls to one of the vitriol, the colour was very permanent; but that if the proportion of galls was increaſed beyond this, the colour was too weak; in this caſe the writing was much refreſhed by waſhing it with a ſolution of vitriol. He alſo endeavoured to aſcertain the beſt proportion of the fluids to the vitriol and the galls. He firſt tried water, and found that by conſiderably diminiſhing the quantity of it the ink was more durable, but too thick for uſe. He found that all waters were much the ſame; but that white wine and vinegar made a more durable ink; but that both theſe were exceeded by a decoction of forty ounces of water to one of logwood, which of itſelf gives a permanent red ſtain. If the colour of the ink ſhould fail, that of the logwood will remain, and it produces, with ink, a much ſtronger and blacker colour than uſual; for the common colour of ink is a purpliſh blue, which, mixed with red, makes a deep black. He did not find any vegetable aſtringent equal in all reſpects to galls.

Mr. Nicholſon ſtates an objection to the uſe of vinegar in the making of ink, which is, that it acts ſo ſtrongly on the pens that they continually require mending. Ink is very apt to become mouldy, which is beſt remedied by the addition of a few cloves reduced to powder; for hot aromatics are excellent preſervers of animal and vegetable matters.

Iron detonates ſtrongly with nitre. It appears to combine with alkalis by fuſion. The calx of iron combines with earths, aſſiſts their fuſion, and imparts a green colour to the glaſs. Iron has a remarkable attraction for ſulphur, and combines with it either by the action of heat or moiſture. A mixture of equal parts of iron filings and ſulphur, made into a paſte with water, becomes hot, emits watry vapours and inflammable air, in a little time the maſs takes fire, and, by attracting the oxygen of the water, becomes converted into green vitriol, in the ſame manner as pyrites. This is the mixture uſed in the production of an artificial earthquake, which will be ſpoken of more fully under the head of earthquakes.

With reſpect to the relations of iron to the other metals, there is little worthy of note, except its attraction for tin, on which is founded the proceſs of tinning iron. In ſome countries iron is made into plates, by being repeatedly heated and ſubmitted to the action of a heavy hammer. In England, however, the plates are not hammered, but rolled out to the proper dimenſions, by being put between two cylinders of caſt iron, caſed with ſteel. When the iron plates have been either hammered or rolled to a proper thickneſs, they are ſcoured with a weak acid, which renders their ſurface perfectly clean and bright, and takes off all the ruſt, which would prevent the adheſion of the tin to their ſurface; they are then wetted with a ſolution of ſal ammoniac, and plunged into a veſſel containing melted tin, the ſurface of which is kept covered with pitch or tallow to prevent its calcination. The tin adheres to each ſide of the plate, and intimately combines with the iron to a certain depth, which renders the tinned plates leſs diſpoſed to harden by being hammered, and forms an excellent defence for the iron againſt the action of air and moiſture.

Biſhop Watſon propoſes it as a queſtion of ſome importance, whether iron of a greater thickneſs might not be advantageouſly tinned? He deſired a workman to break off the end of a large pair of pincers, which had been long uſed in taking the plates out of the melted tin; the iron of the pincers ſeemed to have been penetrated through its whole ſubſtance by the tin; it was of a white colour, and had preſerved its malleability. It is uſual to cover iron ſtirrups, buckles, and bridle bits, with a coat of tin, by dipping them, after they are made, into melted tin; and pins, which are made of copper-wire, are whitened, by being boiled for a long time with granulated tin in a ley made with alum and tartar. On theſe circumſtances he founds two queries; 1. Whether the iron bolts, uſed in ſhip-building, would be preſerved from ruſting by being long boiled in melting tin? 2. Whether it would be poſſible to ſilver iron-plates, by ſubſtituting melted ſilver for melted tin?

It is cuſtomary, in ſome places, to alloy the tin uſed for tinning iron plates with about one-ſeventieth part of its weight of copper. Too much copper renders the plates of a blackiſh hue, but when added to tin in a proper proportion, it enables the manufacturers to lay on a thinner coat of tin without injury to the colour. This practice, however, is rather of prejudice to the duration of the plates. When the tin is heated to a great degree, the covering which it imparts to the iron is thinner but more even. The plates are apt, from this cauſe, to have yellow ſpots on them; but this inconvenience may be removed by boiling the plates for two or three minutes in lees of wine, or, where they cannot be had, ſour ſmall beer, or other ſimilar fluids, may probably be uſed with the ſame ſucceſs.

Iron is juſtly conſidered as a valuable article of the materia medica, and while its utility is conſiderable, it is entirely free from thoſe deleterious and debilitating effects which proceed from moſt of the other metals that are uſed as medicines. The ferrum vitriolatum, or green vitriol, has been already mentioned. The ferri ſubigo is made by merely expoſing iron filings to the air, and moiſtening them with water till they are converted into ruſt. The ferrum tartariſatum is prepared by mixing one part of iron-filings with two of cryſtals of tartar moiſtened with water, and expoſing them to the air for eight days. In this preparation the iron is chiefly brought to the ſaline ſtate by means of the acid of tartar. The ferrum ammoniacale, or flores martiales, is made by mixing one pound of iron filings with two of ſal ammoniac, and applying a briſk heat. The ſal ammoniac ſublimes and carries up ſo much of the iron as to be changed to a deep orange colour. The flores martiales may be made equally well with the colcothar of martial vitriol as with the iron-filings. The tinctura ferri ammoniacalis, or ammoniacal tincture of iron, is made by digeſting one pint of proof ſpirit of wine with four ounces of ferrum ammoniacale. The tinctura ferri muriati is prepared by diſſolving the ruſt of iron in the muriatic acid, and adding a quantity of rectified ſpirit of wine. Wine of iron is obtained by digeſting ruſt of iron with Spaniſh white wine, in the proportion of an ounce to a pint, for a month.

CHAP. XXVIII.

TIN.

General Properties of Tin.—Granulated Tin.—Natural Hiſtory of Tin.—Its Union with the Acids.—Uſe of Tin in improving the red Dyes.—Smoaking Liquor of Libavius.—Aurum Muſivum.—Combinations of Tin with other Metals.—Different Species of Pewter.—Putty.—Application of Tin in dying.—Uſe in Medicine.

TIN, when its ſurface is freſh, is bright, and with reſpect to whiteneſs holds a middle place between lead and ſilver. Tin is the lighteſt of all metals, being only about ſeven times heavier than water. It produces a cracking noiſe when it is bent, though it yields eaſily. It is very ſoft, and, probably from this cauſe, it is ſcarcely at all ſonorous. It is conſiderably malleable, and may be reduced beneath the hammer into laminæ thinner than the leaves of paper (commonly known by the name of *tin foil*) which are of great uſe in ſeveral arts, particularly the foiling of looking glaſſes. Its degree of toughneſs is ſuch, that a wire of tin of the tenth of an inch in diameter ſupports a weight of forty-nine pounds and an half without breaking.

Tin is the moſt fuſible of metals, and melts at a little above the heat of 400°, which is long before it becomes red hot. In paſſing from the fluid to the ſolid ſtate it remains a ſhort time in an intermediate condition, in which it has little more coheſion than wet ſand, and may be broken by a blow of a hammer, or by agitation, into grains. Tin is eaſily calcinable in an obſcure red heat; it at firſt forms a grey pellicle; and in a ſtrong heat it calcines with inflammation into a white powder. The calx of tin reſiſts fuſion more than that of any other metal; from which property it is uſeful to form an opake white enamel, when mixed with pure glaſs in fuſion.

It is obſerved by miners, that though tin is the lighteſt of the metals, its ores are ſome of the heavieſt. Tin is ſeldom or never found in the metallic or reguline ſtate. The ores are often cryſtallized, and of different colours. Thoſe which are of a reddiſh colour generally contain a large proportion of iron. There alſo is a ſulphureous tin ore of a brilliant colour, ſimilar to that of zinc, or golden, like aurum muſivum. The more tranſparent ores of tin often contain arſenic, and this is ſeparated, almoſt entirely, by repeated roaſtings.

In order to reduce the ores of tin, they are firſt cleanſed from foreign admixtures by ſorting, pounding, and waſhing. In the ſmelting of the ore, care is taken to add a larger quantity of fuel than is uſual in the revival of other metals, and to avoid a greater heat than is neceſſary to reduce the ore, in order that the loſs by calcination may be as little as poſſible. Almoſt all the tin uſed in Europe comes from Cornwall, which has been famous for its tin mines from the remoteſt periods of hiſtory.

Tin is five times as dear as lead, and as a ſmall quantity of the latter mixed with a large quantity of the former is with difficulty diſcovered, the temptation to adulterate tin is great, and the fear of detection ſmall. Biſhop Watſon ſtates, in his Chemical Eſſays, that in Cornwall the purity of tin is aſcertained, before it is expoſed to ſale, by what is called its *coinage*. The tin, when ſmelted from the ore, is poured into quadrangular moulds of ſtone, containing about three hundred and twenty pounds of metal, which, when hardened, is called a *block* of tin; each block of tin is coined in the following manner:—the officers appointed by the duke of Cornwall aſſay it, by taking off a piece of one of the under corners of the block, partly by cutting and partly by breaking, and if well purified, they ſtamp the face of the block with the impreſſion of the ſeal of the duchy, which ſtamp is a permiſſion for the owner to ſell, and at the ſame time an aſſurance that the tin ſo marked has been purpoſely examined, and found merchantable *.

The concentrated vitriolic acid acts on tin with the production of ſulphureous vapours, part of the oxygen of the acid, as is uſual in the ſolutions of metals in their reguline ſtate, being abſtracted. The acid diſſolves about half its weight of tin, but not without the aſſiſtance of heat. The ſolution is very cauſtic. The nitrous acid is decompoſed by tin, as it is by moſt of the metals, with great rapidity. The tin is converted into a white calx, which it is very difficult to reduce. M. de Morveau has remarked the formation of a quantity of volatile alkali during the ſolution of tin in the nitrous acid. This is probably owing to a combination of the azote, produced by the acid, with the hydrogen, derived from the decompoſition of the water contained in the menſtruum. The advocates for the phlogiſtic hypotheſis, however, ſay, that the hydrogen is the phlogiſton of the tin ſet at liberty during the ſolution.

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* Borlaſe's Hiſtory of Cornwall, p. 183.

The fuming muriatic acid acts ſtrongly on tin, inſtantly loſing its colour and its property of emitting fumes. The muriatic acid diſſolves more than half its weight of tin, and does not let it fall by repoſe. By evaporation it produces brilliant and very regularly formed needles, which ſlightly attract the humidity of the air. The oxygenated muriatic acid diſſolves tin very readily, and without the leaſt ſenſible effervеſcence. Aqua regia, conſiſting of two parts nitrous and one muriatic acid, combines with tin with effervеſcence and the developement of much heat. The ſolution of tin in aqua regia is uſed by dyers to heighten the colours of cochineal, gum lac, and ſome other red tinctures, from crimſon to a bright ſcarlet, in the dying of woollens. By firſt diſſolving tin in the marine acid, and then boiling the ſolution with nitrous acid diſtilled from manganeſe, M. Hermſtædt has ſucceeded in acidifying tin to ſuch a degree as to convert it into an acid; it had then the form of a white powder, ſoluble in three times its weight of water.

Tin has a ſtronger affinity with the muriatic acid than mercury has, and decompoſes the corroſive mercurial ſublimate. To effect this, the tin is firſt divided by the addition of a ſmall portion of mercury; equal parts of this amalgam and the corroſive ſublimate are triturated together, and the mixture expoſed to diſtillation in a glaſs retort with a very gentle heat. A colourleſs liquor firſt paſſes over, and is followed by a thick white vapour. The vapour becomes condenſed into a tranſparent fluid, which continually emits a thick, white, and very abundant fume. It is called the fuming liquor of Libavius, and is a combination of the muriatic acid and tin. The ſmell of this fluid is very penetrating, and excites coughing. The vapours are not viſible without contact of air, and ſeem to conſiſt of a peculiar gas, which is decompoſable by air, and which then depoſits the calx of tin in the ſame manner as the hepatic gas of Bergman depoſits ſulphur by the contact of air. M. de Fourcroy propoſes it as a query, whether this elaſtic fluid is a compoſition of the oxygenated muriatic acid and tin? When water is added to this fuming liquor in a certain quantity, it becomes ſolid, and ceaſes to emit fumes. It is found that this concrete ſubſtance, when rendered fluid by an increaſe of temperature, is capable of diſſolving more tin without the eſcape of hydrogen gas. Hence it appears that the oxygen neceſſary for the ſolution of this additional quantity of metal is not derived from the water but the acid, and that the acid to impart it muſt be in an oxygenated ſtate. The experiments of M. Adet have thrown much light on the nature of the fuming liquor of Libavius, and are publiſhed in the Annales de Chemie.

Tin is capable of decompoſing all the vitriolic neutral ſalts. Tin has a conſiderable attraction for ſulphur, and eaſily unites with it, when in a ſtate of fuſion, into a black maſs. Aurum muſivum is a combination of tin and ſulphur, obtained by a particular proceſs. Arſenic cannot eaſily be united to tin, on account of the volatility of the former metal. Cobalt unites by fuſion with tin, and forms an alloy in ſmall cloſe grains of a light violet colour. Biſmuth in ſmall quantities, as well as zinc, impart a firmneſs and whiteneſs to tin. Mercury diſſolves tin with great facility, and in all proportions.

The uſes of tin are very numerous. It is applied to many purpoſes in the arts. Its amalgam with quickſilver or mercury is applied to ſilver looking-glaſſes. The uſe of tin in covering plates of iron has been already ſpecified; and it is alſo employed in lining the inſide of copper veſſels. It enters into the compoſition of bronze and bell metal. It is the chief ingredient in the compoſition of pewter. Pewter conſiſts of tin united to ſmall portions of other metallic ſubſtances, ſuch as lead, zinc, biſmuth, and antimony. We have three ſorts of pewter in common uſe; they are diſtinguiſhed by the names of *plate*; *trifle*; *ley*. The plate pewter is uſed for plates and diſhes; the trifle chiefly for ale pints, quarts, &c. and the ley-metal for wine meaſures and other coarſer uſes. Our very beſt pewter is ſaid to conſiſt of one hundred parts of tin to from ten to ſeventeen of antimony.

mony. To this compoſition the French add a little copper. In general the lighteſt pewter is the beſt. The inferior kinds are heavier and ſofter, from a quantity of lead with which they are adulterated. Putty is prepared from the white calx of tin. The ſolution of tin in aqua regia has been already mentioned as uſeful in dying. When it is mixed in the dyer's bath it forms a precipitate, which carries down the colouring matter, and depoſits it on the ſtuff which is to be dyed ſcarlet. The operation of tinning copper will be afterwards deſcribed. The powder of tin has been uſed as a remedy againſt worms in large doſes, and therefore the ſcruples which have been entertained againſt the uſe of veſſels lined with tin muſt be wholly without foundation. Tin has been analized by many chemiſts, with a view to diſcover the quantity of arſenic contained in it. The reſults of theſe experiments have been by no means uniform. The largeſt proportion, however, which has been detected in any tin uſed in commerce, is a grain in an ounce, or one five hundred and ſeventy-ſixth part of the compound; but more frequently no arſenic whatever has been diſcovered.

CHAP. XXIX.

LEAD.

General Properties of Lead.—Red Lead.—Litharge.—Natural Hiſtory of Lead.—Smelting Lead Ores.—Union with Acids.—Plumbum Corneum.—White Lead; how made.—Sugar of Lead.—Union with other Metals.—Common Solder.—Uſes of Lead.—Great Danger from leaden Veſſels.—Devonſhire Colic.—Means of detecting Lead in Liquors.—Medical Uſes of Lead.—Uſes of its Calces in the Arts.

THE appearance of this metal is well known. It is ſo ſoft as to be cut with a knife without much difficulty. It is neither ſonorous nor elaſtic. It has very little tenacity, and therefore cannot be drawn into fine wire. It ſpreads eaſily under the hammer, but cannot be extended into very thin leaves like gold, ſilver, and tin. Its ſpecific gravity is rather greater than that of ſilver, being eleven times heavier than water, and it is exceeded in this reſpect by only three metals, gold, platina, and mercury. Lead melts at the five hundred and fortieth degree of Fahrenheit's thermometer, before it becomes red hot.

Lead, like tin, at a certain point between its fluid and ſolid ſtates, poſſeſſes very little coheſion, and may be ſeparated by a ſmart blow with a hammer into grains, which are uſed in aſſaying the ores of gold and ſilver.

Lead, ſoon after it is melted, acquires a film on its ſurface, which preſents in ſucceſſion a variety of colours. This film becomes thicker, and of a grey colour, by the continuance of the calcination, and is then called plumbum uſtum. If the firſt pellicle is removed, another is quickly formed, and in this way almoſt the whole of the lead may be converted into a greyiſh powder tinged with green and yellow. This powder, being ground in a mill and waſhed, becomes of a more yellow colour. By further expoſure to a moderate heat, aſſiſted by the reverberation of the flame of the fuel on the ſurface of this calx, it gradually aſſumes an orange, and then a bright red colour, and is thus, in about forty-eight hours, converted into the ſubſtance called minium, or *red lead.* If lead is, in the phraſe of the chemiſts, urged with a more violent and ſudden heat, the appearances which it exhibits are different. It is firſt converted into a flaky ſubſtance, called litharge, which, by the proceſs juſt deſcribed, may be converted into minium, but which, by an increaſe of heat, becomes fluid, and acts ſo powerfully as a ſolvent on earthy ſubſtances as quickly to make its way through ordinary crucibles.

All theſe calces of lead may be eaſily reduced to the metallic ſtate, by melting them in contact with inflammable ſubſtances. In calcining and reducing ſixty hundred weight of lead, there is found to be a loſs of eight hundred. This loſs was explained by the old chemiſts on the ſuppoſition of the eſcape of a volatile ſubſtance called by them mercurial earth, but which was never proved to have any exiſtence.

The loſs, however, ought to be attributed in ſome meaſure to the evaporation of part of the lead itſelf, and partly to the imperfection of the proceſs, as it is ſeldom performed ſo accurately as to reduce the whole of the calx.

Lead is very rarely found native. It is ſometimes found in the form of a calx, called native ceruſe, or lead ochre, or in that of lead ſpar of various colours, and which are in general either rhomboidal or cubical. Lead combined with ſulphur is called galena, which is compoſed in general of laminæ which have nearly the colour and aſpect of lead, but are more brilliant, and very brittle. A great variety of theſe ores have been diſcovered, which it will not be neceſſary to enumerate. Lead, in ſome inſtances, has been found combined with various acids; the vitriolic, the phoſphoric, the carbonic, and the arſenical. The ores of lead very commonly contain ſilver, and ſometimes antimony.

In ſmelting lead ores the ſulphur is diſſipated for want of a proper apparatus for collecting it. According to biſhop Watſon's experiments, the Derbyſhire lead ores contain in general from one-ſeventh to one-eighth part of their weight of ſulphur. One of the chief circumſtances to be attended to in the ſmelting of lead ores, particularly ſuch as contain much ſulphur, is to keep them for ſome hours in a moderate heat, by which that ſubſtance may be gradually diſſipated. After this the fire muſt be raiſed to fuſe the maſs completely, by which the metal flows through the ſcoriæ, and is collected in the cavity at the bottom of the furnace. The ſcoriæ being then thickened by the addition of lime, ſo that they may be raked aſide, a ſtopper is drawn out and the lead ſuffered to flow into an iron pot, whence it is laded into moulds, which form it into the maſſes called pigs of lead.

Lead is ſoluble in the concentrated vitriolic acid, by the aſſiſtance of heat only. The lead then forms, with the vitriolic acid, a ſubſtance ſcarcely ſoluble in water. It ſeems to have a peculiar affinity with this acid, and leaves all others to combine with it, which is not the caſe with the other metals.

The nitrous acid acts ſtrongly on lead. When the acid is concentrated, it corrodes the lead into a white calx; but if it is conſiderably diluted, it diſſolves the lead. This ſolution does not afford a precipitate on the addition of water. Its cryſtals, obtained by cooling, are of an opake white. This ſalt decrepitates in the fire, and melts with a yellowiſh flame when laid on ignited charcoal. The calx, which is at firſt yellow, is quickly reduced into globules of lead. The vitriolic acid added to this ſolution combines with the metal, and forms a precipitation. The marine acid, in the ſame manner, ſeizes the lead, and forms a combination, which, if expoſed to heat, melts into a maſs of a brown colour, called plumbum corneum, from ſome reſemblance to the combination of the ſame acid with ſilver, called argentum corneum.

The acetous acid, or vinegar, acts on lead, particularly when applied to it in ſteam, in which proceſs the action of the air probably aſſiſts that of the acid. To procure white lead, ſheets of lead are rolled up ſpirally,

ſpirally ſo as to leave the ſpace of about an inch between each coil, and placed vertically in earthen pots, which have ſome good vinegar at the bottom. The pots are covered, and expoſed to a gentle heat for a conſiderable time by ſurrounding them with horſe-dung. The ſteams of the vinegar circulate in the veſſel, and attach themſelves to the ſurface of the lead, converting it into white flakes, which come off when the lead is uncoiled. The remaining lead is again expoſed to the ſteams of the vinegar, till another cruſt is formed, and the proceſs is repeated till its whole ſubſtance is converted into the white flaky matter called ceruſe, or white lead.

Such are the deleterious effects of lead, when taken into the human body, that the wretched labourers in white lead works are ſeldom known to ſurvive more than three years, when they expire in excruciating pain from the Devonſhire colic, loſe the entire uſe of their limbs, or gradually pine away by a waſting maraſmus. In a well regulated community ſuch works ought to be entirely prohibited, or at leaſt only carried on by the worſt of felons, whoſe lives would be otherwiſe forfeited.

Lead, after being thus reduced to the ſtate of ceruſe by the fumes of the acetous acid, may be eaſily diſſolved in the ſame acid in a fluid ſtate, and the ſaline matter thus formed, is then called, from its ſweet but aſtringent taſte, ſugar of lead.

To have this ſalt of lead in the form of tranſparent cryſtals, it is neceſſary to uſe much acid; if there is not a redundancy of acid, moſt of the cryſtals are ſmall and mealy. This may be remedied by diſſolving them again in diſtilled vinegar, and repeating the cryſtallization. In this manner ſo much of the acid may be united to the metal as to change the appearance of the ſalt to that of an oily fluid. This metallic ſalt, like others, may be decompoſed by an alkali. In all theſe caſes the precipitates of lead are white, but the calces are coloured.

The ſaccharum ſaturni, or ſugar of lead, may be decompoſed by heat alone, for, when expoſed to a gradual heat, the acid riſes in a very concentrated ſtate. This proceſs is attended with the remarkable phenomenon of the production of a quantity of ardent ſpirit. By the phlogiſtic hypotheſis this fact admitted of explanation, by ſuppoſing that the principle of inflammability of the metal combined itſelf with a portion of water, contained in the acetous acid, and thus formed alcohol, or ſpirit. Upon M. Lavoiſier's principles, however, it may be much better accounted for. It has been proved by him, that alcohol is a combination of hydrogen, charcoal, and a ſmall quantity of oxygen. Now all theſe principles exiſt in vinegar, the baſis of which is hydrogen and charcoal, brought to the ſtate of an acid by their union with a large proportion of oxygen. The chief difference, therefore, between vinegar and alcohol is, that the former contains much more oxygen. As part of the oxygen, however, after this operation, is ſtill retained by the lead, which is not reduced to its metallic form, it is very natural to ſuppoſe that part of the fluid which paſſes over ſhould be reduced to the ſtate of alcohol.

Nitre, heated with lead, calcines it into a yellow ſubſtance, but without producing deflagration. Sal ammoniac and common ſalt are decompoſed by being heated with the calces of this metal, but the neutral ſalts, in general, are not acted on by it. Sulphur readily diſſolves it by the aſſiſtance of heat, and produces a brittle compound of a deep grey colour and brilliant appearance. Phoſphorus may be united with lead, and forms with it a malleable and ſoft compound, not very different in appearance from lead itſelf.

Lead combines with biſmuth, and affords a metal of a fine cloſe grain, which is very brittle. The alloy of lead with arſenic has not been examined. Nickel, manganeſe, cobalt, and zinc, do not unite with lead by fuſion. With antimony it forms a brittle alloy, with ſome brilliant facets. Mercury diſſolves lead with the greateſt facility. Lead unites very eaſily with tin. Two parts of lead with one of tin form an alloy more fuſible than either of the metals taken ſeparately, and which is, therefore, uſed by plumbers as a ſolder.

Lead is uſed for a great number of economical purpoſes. Leaden veſſels, however, are very apt to communicate injurious properties to all fluids which are kept in them for any length of time, and ſhould wholly be rejected in the management of ſuch fluids as contain an acid capable of acting immediately on the metal, and of diſſolving ſo much as irreparably to injure the conſtitutions of perſons who are in the habit of uſing them. Inſtances in which lead received into the body has produced the lingering and painful diſorder called the painter's colic, or the colic of Poitou, are too numerous to leave any queſtion as to the pernicious effects of this metal. The liquors in which an admixture of lead is moſt to be apprehended are, cyder, wines, and rum. In Devonſhire, from the great uſe of cyder, and the improper methods of making it, by which, either through careleſſneſs or deſign, lead becomes diſſolved in it, the diſorder above mentioned prevails ſo much, as to have obtained the name of the Devonſhire colic.

It is unfortunately the caſe, that lead diſſolved in vinous liquors is capable of imparting a rich and agreable flavour to them, and even of reſtoring them after they have become conſiderably acidulated. The temptation to uſe lead, therefore, in this way is great; and ſo long as dealers are ignorant of the pernicious effects of this metal, or want honeſty to prefer the ſafety of their cuſtomers to their own profit, there is no reaſon to hope that the habit of occaſionally uſing it will be aboliſhed. The adulterating of wines in this manner was ſo common a few years ago in France, that it was unſafe for ſtrangers to uſe the wines which were ſold at their inns. It is very deſirable to be furniſhed with the means of detecting this pernicious ingredient, and the following are recommended by an author, whoſe ſpeculations even on the moſt common ſubjects have ever been directed to the public good, and are always productive of public advantage *: Boil together, in a pint of water, an ounce of quick lime and half an ounce of flowers of brimſtone, and when the liquor, which will be of a yellow colour, is cold, pour it into a bottle, cork it up, and reſerve it for uſe. A few drops of this liquor, being let fall into a glaſs of wine or cyder containing lead, will change the whole into a colour more or leſs brown, according to the quantity of lead which it contains; if the wine is wholly free from lead, it will be rendered in ſome meaſure turbid by the liquor, but the colour will be rather a dirty white than a blackiſh brown.

In general, a ſolution of common liver of ſulphur will precipitate the lead, but unfortunately iron as well as lead is precipitated by both theſe teſts, and it is ſaid that many honeſt wine merchants have been ruined by this means, by having unjuſtly fallen under the ſuſpicion of adulterating their wines with lead. M. Hannemann has publiſhed a paper in the Journal de Phyſique, in which he aſſures us, that the following liquor, whilſt it does not precipitate iron, will precipitate lead and copper of a black colour, and arſenic of an orange. Mix equal parts of oyſter ſhells and crude ſulphur in fine powder, and put

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* Biſhop Watſon. This excellent and truly reſpectable author, this great ornament of the Engliſh church, will, I flattar myſelf, forgive the very free and frequent uſe I have made of his incomparable Eſſays. He has ever been

"Mihi magnus Apollo."
"My guide, philoſopher——"

and, if I was not afraid of preſuming too far, I would add the concluſion of that well known line.

put them into a crucible; apply a briſk fire in an air furnace, ſo as to make the crucible of a white heat for about fifteen minutes. The maſs, when cold and powdered, ſhould be kept in a bottle well corked. To prepare the liquor, put one hundred and twenty grains of this powder, and one hundred and eighty grains of cream of tartar, into a very ſtrong bottle, fill it with water, let it boil for an hour, and then cool. Cork the bottle, and frequently ſhake up the ingredients. After it has ſtood for ſome hours to ſettle, pour off the clear liquor, and put it into little bottles, which contain about an ounce, having previouſly dropped into each twenty drops of marine acid. Cork them cloſe by means of wax mixed with a little turpentine. One part of this liquor, mixed with three parts of the wine ſuppoſed to contain noxious metallic particles, will diſcover, by a black precipitate, the ſmalleſt particle of lead, copper, &c. but will not affect the iron contained in it. Pure wines are not diſcoloured by the addition of this liquor.

The deleterious effects of lead are not confined to its action on the ſtomach. Men who work in the manufactories for the different preparations of lead are liable to complaints very ſimilar to thoſe who drink liquors containing lead. Painters are ſo liable to this complaint, from the lead contained in paint, that it has obtained, on this account, the name of the painter's colic.

Lead is the moſt powerful article in the materia medica in reſtraining hemorrhages and exceſſive diſcharges, but its uſe is ſo dangerous that it is not very often employed internally by phyſicians. The preparations of lead are, however, highly beneficial, without being generally dangerous, as ingredients in plaſters and other external applications, particularly in the well known Goulard's extract.

The calces of lead are uſed in making ſome kinds of glaſs, of which they increaſe the ſolidity, and to which they impart a kind of unctuoſity which fits them for being cut and poliſhed with leſs danger of breaking. Lead enters particularly into the compoſition of flint glaſs, and the compoſitions called paſtes, or artificial gems. The chief defect of flint glaſs is, that it is apt to be of unequal denſity, which renders it difficult to find pieces of any conſiderable dimenſions free from ſtriæ. Litharge is alſo employed by potters for glazing their ware.

The uſes of red and white lead, as pigments, are well known The common red wafers are coloured with red lead, as may be eaſily ſeen by holding one of them in the flame of a candle, when the lead will be reduced, and appear in little globules; theſe wafers ſhould, therefore, never be left in the way of children, as they may be induced to ſwallow them, and may conſequently ſubject themſelves to all the ill effects ariſing from this fatal poiſon. The beſt red wafers are coloured with vermilion.

CHAP. XXX.

COPPER.

General Properties of Copper.—Its Natural Hiſtory.—Turquoiſe Gem.—Smelting and refining of Copper.—Antique Statues preſerved by the Green Ruſt.—Union with Acids.—Blue Vitriol.—Colouring of Guns.—Cuprum Ammoniacum.—Verdigris.—Union with Metals.—White Copper.—Pinchbeck.—Gun Metal.—Bell Metal.—Metal of ancient Statues.—Bronze.—Speculums of Reflecting Teleſcopes.—Pot Metal.—Tinning of Copper.

COPPER is a metal of a peculiar red colour, and when its ſurface is freſh and clean it has a conſiderable degree of ſplendor. It is hard, ductile, and malleable to a conſiderable degree, and remarkably ſonorous. It has a peculiar and unpleaſant ſmell, particularly when rubbed. Its taſte is ſtyptic and nauſeous. Its tenacity is ſuch, that a copper wire of one tenth of an inch in diameter is capable of ſupporting a weight of about three hundred pounds. Its fracture exhibits the appearance of ſmall grains. Its gravity is about nine times that of water.

Copper has a great degree of ſtrength and rigidity, approaching to that of iron. It is not inflammable like iron, and is therefore uſed in gunpowder works, inſtead of that metal. It does not admit, like iron, of being welded, but this defect is compenſated by its greater fuſibility, by which it may be always formed into the deſired ſhape. It requires for its fuſion about the ſame heat as gold and ſilver. When in fuſion, for which it requires a ſtrong white heat, it appears of a blueiſh green colour, which ariſes from a flame of that colour on its ſurface. By a very violent heat it boils, and is volatized partly in the metallic ſtate. Copper, in a heat far leſs than is ſufficient to melt it, becomes calcined at its ſurface, and exhibits various colours. In a greater heat than is ſufficient to produce this effect, its ſurface is converted into thin ſcales, which may be eaſily ſcraped off.

Copper is ſometimes found native, having the metallic ſplendour, the malleability, and all the properties of ordinary copper. It has ſometimes the form of plates, ſometimes that of fibres or branches, and is ſometimes cryſtallized. Copper, in its metallic ſtate, is ſometimes found depoſited on ores of iron, in which caſe it muſt be conſidered as having been ſeparated from native vitriol of copper by the ſuperior attraction of iron for the vitriolic acid. The native ſolutions of copper often depoſit that metal in a calcined ſtate in beds of calcareous earth. The turquoiſe ſtone is the tooth of an animal, penetrated with the blue calx of copper. Copper is generally found, however, contained in ores. Theſe are frequently mineralized by ſulphur. What are improperly called the vitreous ores of copper are of this kind; they are brown, red, and grey, and theſe colours are frequently mixed with a greeniſh or violet tinge. Theſe melt eaſily, are very ponderous, may be ſcratched or even cut with a knife, a knife, and are very rich in metal, as an hundred pounds of them uſually yields from eighty to ninety of copper. The azure copper ore differs from the former chiefly in containing a conſiderable quantity of iron. The grey copper ores, which have not much ſplendor, conſiſt of copper, ſulphur, arſenic, and ſome iron. What are called copper pyrites contain in reality more iron than copper, but yield enough of the latter metal to anſwer the expence of working them; they are generally of a yellow and brilliant aſpect. Copper is alſo, in ſome ſpecimens, found united with ſlate, pitcoal, zinc, and antimony.

Copper is ſeparated from its ores by different proceſſes, according to the nature of thoſe ores. If they contain much ſulphur, after being pounded and waſhed, they are roaſted in the open air to diſpel the ſulphur, which in a great meaſure ſupplies the want of other fuel. The ore is afterwards roaſted once or twice more with wood, and is melted in an open fire into a maſs called a mat of copper. In this ſtate it ſtill contains a large quantity of ſulphur, which the workmen continue to expel by repeated roaſtings and fuſions, till the metal acquires a certain degree of purity, and is called black copper, which is ſomewhat malleable, but ſtill contains ſulphur, iron, and generally ſome other impurities. In order to get entirely rid of theſe, the copper is haſtily fuſed with three times its weight of lead. The lead unites with the copper and expels the iron, and the imperfect metals, which happen to be mixed with the copper, are expelled by cupellation. The copper is afterwards refined, by keeping it heated in crucibles for a conſiderable time, ſo that it may throw up all the foreign ſubſtances it ſtill contains in the form of ſcoriæ. It is examined, from time to time, by immerſing iron rods in it, which become coloured with a ſmall quantity of copper, and its purity is judged of by the brilliant redneſs of theſe ſpecimens.

Copper is not ſo eaſily acted on by the air as iron. In ſituations, however, where it is expoſed to the action of moiſt air, it becomes gradually covered with a green ruſt or calx, which is ſapid and ſoluble in water. This ruſt never penetrates into the ſubſtance of copper, but ſeems rather to contribute to the preſervation of its internal parts, as may be ſeen in antique medals and ſtatues of this metal.

Copper does not unite with earthy matters; its calx, however, promotes their fuſion, and forms with them glaſſes of a deep brown. Cauſtic fixed alkalies, digeſted in the cold with filings of copper, aſſume, after a time, a light blue colour, the copper becoming covered with a powder of the ſame colour. Copper, treated in the ſame manner with volatile alkali, produces, in a few hours, a deep and moſt beautiful blue, the quantity of copper taken up being very inconſiderable. From the ſtrong blue colour produced by the action of copper and volatile alkali, they become excellent teſts of the preſence of each other in any body, fluid or ſolid.

Copper is in general eaſily acted on by acids. The vitriolic acid, however, does not act on it unleſs concentrated and aſſiſted by heat; it then corrodes the copper into a brown matter of a thick conſiſtence, which, by the addition of water, affords a ſolution of a deep blue colour. If this ſolution is evaporated to a certain point, and ſuffered to cool, long rhomboidal cryſtals are afforded of a deep blue colour, called vitriolated copper, or blue vitriol; it appears therefore that vitriolic acid forms, with iron, green cryſtals; with zinc, white cryſtals; and with copper, blue cryſtals.

Copper may be obtained from the ſolution of blue vitriol, by dipping into it pieces of iron. The vitriolic acid diſſolves the iron in preference to the copper, and depoſits the latter, in its metallic form, on the ſurface of the iron. Upon this circumſtance is founded the proceſs for browning fowling pieces. The barrels are moiſtened with a ſolution of blue vitriol, which diſſolves the iron to a very inconſiderable depth, and depoſits in its place a thin lamina of copper.

Blue vitriol has a ſtrong ſtyptic taſte, and is in ſome degree cauſtic. Expoſed to heat it parts with its water of cryſtallization, melts, and becomes of a pale blue colour. A ſtrong heat is required to ſeparate from it the vitriolic acid, which adheres more firmly to copper than iron. Blue vitriol is decompoſed by magneſia and by lime. If the mild vegetable alkali is poured into a ſolution of blue vitriol, a precipitate is formed of a pale blue colour, which, however, becomes green by expoſure to air: in this experiment no effervеſcence takes place, and we may therefore conclude that the carbonic acid of the mild alkali unites with the calx of copper. Volatile alkali precipitates the ſolution of blue vitriol, in the ſame manner, of a blueiſh white colour; but the mixture very ſoon becomes of a deep blue colour, which happens from the alkali re-diſſolving the precipitate. In order to obtain the *cuprum ammoniacum*, which has been recommended as a remedy for epilepſy, add volatile alkali till the whole precipitate of copper is rediſſolved, then ſet the ſolution before a fire in a flat veſſel, and let it gradually evaporate, which ſhould be done with a heat not exceeding that of the human body; the matter which remains at the bottom, in the form of a cruſt, muſt be rubbed in a mortar, that it may be intimately mixed.

The blue vitriol of the ſhops is made by means of the action of ſulphur upon copper; theſe are gently calcined together; the ſulphur attracts the oxygen of the atmoſphere, and unites with the copper into a ſoluble powder, which is afterwards cryſtallized into blue vitriol.

A beautiful green paint may be precipitated from blue vitriol, by means of white arſenic diſſolved in water together with vegetable alkali.

The nitrous acid diſſolves copper with great rapidity, without the aſſiſtance of heat, with the production of a large quantity of nitrous gas. Part of the metal falls down in the form of a calx, and the filtrated ſolution, which is of a much deeper blue colour than the vitriolic ſolution, affords cryſtals by ſlow evaporation. This ſalt is more corroſive than vitriolated copper; it ſo powerfully attracts the humidity of the atmoſphere that it deliqueſces, unleſs kept in cloſe veſſels or in a very dry place. When melted in a crucible it emits large quantities of nitrous vapour and becomes brown, in which ſtate it is merely a calx of copper. In a dry and hot air this ſalt becomes covered with a green efflореſcence. It detonates ſlightly on burning coals.

The muriatic acid acts with great difficulty on copper in its metallic ſtate, but diſſolves its calces with conſiderable rapidity. This may be eaſily accounted for from the ſtrong attraction which the baſe of the muriatic acid has for oxygen, ſo that it will not part with any of it to oxygenate the metal, and no metal is ſoluble in acids without being firſt oxygenated. When, however, the metal has been prepared for ſolution by an union with oxygen, that is by being calcined, the acid then diſſolves it, and adheres very cloſely, ſo that it is with great difficulty ſeparated by heat. The muriatic ſolution of copper is of an agreeable green colour, and affords cryſtals of the ſame, and in this particular differs remarkably from the vitriolic and nitrous combinations of copper, which are of a deep blue.

The vegetable acids diſſolve copper when calcined, but ſcarcely act on it in its metallic ſtate. It is a curious circumſtance, which has never been ſufficiently explained, that vegetable acids act more powerfully on copper when cold than when they are heated. Thus pickles, or even lemon juice, may be boiled in clean copper veſſels without danger; and yet, if left for a few hours, when cold, in copper veſ-

ſels,

ſels, they are apt to contract a metallic impregnation ſufficient to produce dangerous effects. This fact has by ſome chemiſts been attributed to the ſteams of the boiling fluid keeping off the air, which is thought to aſſiſt the action of the acids.

Verdigris is a very beautiful green ruſt or calx of copper, much uſed by painters, and prepared in large quantities near Montpelier in France. The proceſs for making verdigris was thus deſcribed by M. Monnet, of the Royal Society of Montpelier, about the year 1750. Vine ſtalks, well dried in the ſun, are ſteeped, during eight days, in ſtrong wine, and afterwards drained; they are then put into earthern pots, and wine is poured upon them; the pots are kept carefully covered. The wine undergoes the acetous fermentation, which in ſummer is finiſhed in ſeven or eight days, but requires a longer time in winter, though this operation is always performed in cellars. When the fermentation is ſufficiently advanced, which may be known by obſerving the inner ſurface of the lids of the pots, which, during the progreſs of the fermentation, are continually wet by the moiſture of the riſing vapours, the ſtalks are to be taken out of the pots. The ſtalks are by this method impregnated with all the acid of the wine, and the remaining liquor is only a very weak vinegar. The ſtalks are now drained ſome time in baſkets, and layers of them are put into earthern pots with plates of Swediſh copper, ſo diſpoſed that each plate may reſt on and be covered with layers of ſtalks. The pots are covered with lids, and the copper is thus left expoſed to the action of the vinegar for three or four days or more, in which time the plates become covered with verdigris. The plates are then taken out of the pots, and left in the cellar three or four days, at the end of which time they are to be moiſtened with water, or ſome of the weak vinegar above mentioned, and left to dry. When this moiſtening and drying of the plates has been repeated three times, the verdigris will be found to have increaſed conſiderably in quantity, and it may then be ſcraped off for ſale.

A ſolution or eroſion of copper may be obtained by employing ordinary vinegar inſtead of wine, as is directed in the above proceſs. It would not, however, have the unctuoſity of the beſt verdigris, which quality is neceſſary for painting. Good verdigris cannot be prepared, except with a vinous acid, or a ſolvent partly acid and partly ſpirituous. Accordingly the ſucceſs of the operation depends chiefly on the degree of acetous fermentation to which the wine has been carried.

By diſtilling verdigris, the acetous acid may be ſeparated in a concentrated ſtate, and of a ſtrength equal, or perhaps ſuperior, to the muriatic acid.

Copper is capable of a very ſlight detonation with nitre. It decompoſes ſal ammoniac, and at the ſame time the volatile alkali is in ſome meaſure reſolved into its conſtituent parts, azote and hydrogen.

Sulphur and phoſphorus may be united to copper; they deprive it of its metallic ſplendor, and change it to a black colour. If plates of copper are ſtratified in a crucible with ſulphur, they unite, and form a compound which is uſed in the dying and painting of calicoes. Liver of ſulphur and hepatic gas have a ſtrong action on copper; the former diſſolves the metal by the dry, as well as by the humid way; the latter ſtrongly colours the ſurface, but its effect has not yet been well examined into. Oils alſo diſſolve copper, particularly thoſe of an aromatic kind.

There are few metals which will not form alloys with copper. A metallic compound is made with arſenic in imitation of ſilver, but it ſoon tarniſhes. In treating of zinc, the proceſs for making braſs has been deſcribed. Pinchbeck is a kind of braſs made in imitation of gold. Copper is the baſe of gun metal and bell metal. Gun metal is ſaid to conſiſt of copper, with about one tenth part of tin; bell metal, of copper with about one fifth of tin. It may in general be obſerved, that a leſs proportion of tin is uſed for making church bells than clock bells, and that a little zinc is added for the bells of repeating watches, and other ſmall bells.

Copper, in a ſtate of fuſion, is liable to a violent exploſion if touched with any humidity. In the caſting of bells and cannon they are particularly careful to have the moulds dry; for if the leaſt moiſture finds acceſs, it is ſuddenly converted into vapour, and by its expanſion throws the metal to a conſiderable diſtance, to the great danger of the perſons preſent.

The beſt poſſible proportions of copper and tin, for the above purpoſes, have never, I believe, been accurately aſcertained. The metallic compound uſed by the Romans for their ſtatues and plates for inſcriptions, is handed down to us by Pliny the naturaliſt. They firſt melted a quantity of copper; into the melted copper they put a third of its weight of old copper, which had been long in uſe; to every hundred pounds weight of this mixture they added twelve pounds and an half of a mixture compoſed of equal parts of lead and tin. Tin melted with copper forms the compound called bronze. Of this compound the ſpecific gravity is always greater than would be deduced by computation from the quantities and ſpecific gravities of its component parts. There ſeems to be a happy relation between theſe metals, which fits them for forming, in conjunction, compounds of great firmneſs, denſity, and cloſeneſs. From theſe properties they admit of an excellent poliſh, and Pliny accordingly informs us, that the beſt looking glaſſes of his time were made of a compoſition of copper and tin. But the attention of philoſophers is more particularly directed to the mixture of copper and tin, on account of its being the ſubſtance of which the ſpeculums of reflecting teleſcopes are made. Mr. Mudge found, after a number of trials, that fourteen ounces and an half of grain tin, with two pounds of copper, made the beſt compoſition for this purpoſe; an addition of half an ounce more of the tin rendered the compoſition too hard to be properly poliſhed.

Pot metal is made of copper and lead, the latter being one fourth or one fifth of the weight of the former. Lead, however, does not ſeem to have any remarkable attraction for copper, and does not promote its fuſion, unleſs the lead is heated to a high degree; the copper then diſſolves with ſome degree of effervеſcence. On allowing the compound to cool, the copper ſeparates again, and forms little grains in the maſs, through which the lead remains diſperſed. It is eaſy to ſeparate the lead again from the copper, if the maſs is expoſed in a furnace; for the lead melts firſt and leaves the copper; the lead, however, which runs off at firſt, contains ſome of the copper, which may be eaſily ſeparated by melting the lead and taking off the ſcum, which contains the copper. Silver is ſeparated from copper by melting the latter with three times its weight of lead; the lead is then melted out, and carries with it the ſilver. The ſilver is afterwards ſeparated from the lead by the calcination of the latter metal.

From the bad effects which have been experienced from impregnations of copper in aliments dreſſed in copper veſſels, it has become a very general cuſtom to cover theſe veſſels with an internal coat of ſome other metal. The method of tinning iron has been deſcribed, and that of tinning copper is very ſimilar, except that the compoſition for covering the ſurface of copper conſiſts of about one part of lead to two of tin, whereas iron is covered with tin alone. Zinc has been recommended as a ſubſtitute for tin in theſe operations, and has the advantage of ſuperior hardneſs. The method of tinning copper veſſels is by making their internal ſurface perfectly bright, and then waſhing them with a ſolution of ſal ammoniac. The veſſel is next heated, and the tin or metallic mixture is melted and poured into it, and being made to flow over every part of the ſurface of the veſſel, it incorporates with the copper, and when cold remains united with it. Roſin, or pitch, are ſometimes uſed to prevent the tin from being calcined, and the copper from being ſcaled, either of which circumſtances would prevent the adheſion of the tin. Biſhop Watſon eſtimated the quantity of pure tin which is uſed in tinning a definite ſurface of copper, and found that half an ounce of tin was ſpread over two hundred and fifty-four ſquare inches, or ſomewhat leſs than a grain of tin on each ſquare inch; but the ſame author ſuſpects, that not a quarter of a grain of tin is ſpread over a ſquare inch in the ordinary mode of tinning, and therefore recommends it as a neceſſary caution againſt the coat being rubbed off, and the copper becoming expoſed, to make it as thick as poſſible, and to uſe tin nearly pure.

A very excellent method of tinning, and one much practiſed in England, is, to make uſe of pure tin, and hammer it on the copper. It ſeems probable, however, that when copper veſſels are kept well ſcoured, that no danger will ariſe from them in the dreſſing of animal food, or even of vegetable aliments, unleſs ſuffered to remain in the veſſels when cold.

CHAP. XXXI.

MERCURY.

Great Attraction of this Metal for the Matter of Heat.—Quickſilver; rendered ſolid; malleable.—General Properties of Quickſilver.—Hydrargyrus calcinatus.—Natural Hiſtory of Mercury.—Cinnabar.—Native Vermilion.—Action of Acids on this Metal.—Turbith Mineral.—Red Precipitate.—White Precipitate.—Corroſive Sublimate.—Calomel.—Keyſer's Pills.—Ethiop's Mineral.—Vermilion.—Amalgams.—Gold made brittle by Mercury.—Mode of gilding Metals.—Uſe of Quickſilver in extracting the precious Metals from the Earth.—Making of Looking Glaſſes.—Conditions neceſſary for the Operation of Mercury on the human Body.

THE circumſtance which moſt remarkably diſtinguiſhes mercury, or quickſilver, from the other metals, is its ſtrong attraction for heat, ſo that it retains the ſtate of fluidity at the ordinary temperature of the atmoſphere, and at the temperature of 600 degrees of Fahrenheit is converted into vapour; few of the other metals, therefore, melt at ſo low a point as that at which mercury boils and is volatilized. It was long taken for granted that there was ſomething peculiar in mercury, which rendered it neceſſarily fluid; but the academicians of Peterſburg have proved that this is an erroneous idea, and ſhewn that mercury differs from other metals merely in the degree of heat at which it paſſes from its ſolid to its fluid ſtate. The congelation of mercury has been effected in a variety of inſtances by the help of the nitrous acid and ſnow, or pounded ice, commonly called the freezing

ing mixture, and the congelation is found to take place at the thirty-ninth degree below 0 of Fahrenheit's thermometer. Mercury, in its ſolid form, is found to have conſiderable malleability, but this cannot be proved to its fulleſt extent, becauſe the hammering of it produces very ſoon a degree of heat ſufficient to melt it.

Mercury being a metal in a ſtate of fuſion, always affects the form of globules when it is divided; and when it is confined in a bottle, its ſurface is convex, from the ſtrong attraction of its particles for each other. If the veſſel, however, in which mercury is confined, is metallic, its ſurface appears concave, from the tendency which it has to unite itſelf to the ſides of the veſſel, which attraction overcomes that between its own particles.

When mercury is ſubmitted to that degree of heat at which it is volatilized, and is at the ſame time expoſed to the action of atmoſpherical air, it is gradually converted into a calx of a red colour, the hydrargyrus calcinatus of the London pharmacopeia. A greater heat, however, revives this metallic calx, and at the ſame time the vital air is again extricated.

Mercury is not ſenſibly acted on by expoſure to air, but by long continued agitation it becomes partly converted into a very fine black powder. The mercury is not changed in this experiment, unleſs, perhaps, it ſhould be found that it abſorbs ſome part of the vital air contained in the veſſel in which it is confined. By a ſlight heat, or by trituration in a warm mortar, it may be made to reſume its uſual fluidity and brilliancy.

Mercury is found in the earth, either in its native metallic ſtate, or combined with ſulphur, when it is called cinnabar. Running mercury is found in globules, or larger maſſes, in friable earths or ſtones, and moſt commonly in the clefts or cavities of its ores. It is more frequently, however, imbedded in calcareous earths or clays of different colours, from which it may be ſeparated either by trituration or lotion, the ſmaller globules coaleſcing by mutual contact into larger; or by diſtillation.

More mercury is found in the ſtate of cinnabar than in its metallic form. This ore conſiſts of mercury and ſulphur combined together in different proportions. Cinnabar is ſometimes found in the form of a brilliant red powder, and is then called native vermilion, ſometimes in an indurated ſtate, and though generally red, has been ſometimes obſerved of a yellowiſh or blackiſh caſt. It it is moſtly opake, but ſome ſpecimens are as tranſparent as a ruby.

Mercury is too volatile to admit of the ſulphur being ſeparated from it by roaſting; theſe ſubſtances are both ſo volatile that they would riſe together. In order to ſeparate mercury from its ore it is neceſſary to add quick lime, or iron filings, unleſs ſome ſubſtances of a ſimilar nature happen to be naturally mixed with it; the maſs is then ſubmitted to diſtillation, and the calcareous earth, or iron filings, by ſuperior attraction, detain the ſulphur, while the mercury comes over in the ſtate of vapour, and is condenſed in the receiver. Different cinnabars yield from three parts to ſeven parts in eight of their weight of mercury. Mercury has ſometimes been found united with the muriatic and vitriolic acids, and with the ores of ſome other metals. It is thought to be not abundant in nature; but this opinion may be partly owing to its volatility, which may prevent it from being diſcovered in many minerals that may contain it. Moſt of the mercury in commerce is afforded by the mines of Idria in the Auſtrian dominions, Almaden in Spain, and Guancavelica in Peru.

The vitriolic acid does not act on mercury unleſs concentrated and conſiderably heated; it then corrodes it into a white maſs, and the vitriolic acid is rendered partly volatile by the abſtraction of oxygen. The greateſt part of this maſs, which weighs conſiderably more than the mercury made uſe of, is a calx of mercury united to a ſmall portion of vitriolic acid, but part of it is a perfect ſalt, formed by the union of the vitriolic acid and mercury. If boiling water is added to it, it aſſumes a bright lemon colour, which is owing to the abſtraction of the vitriolic acid, the preſence of which rendered the maſs white. The more boiling water is uſed the yellower is the remaining powder, which, after repeated effuſions of water, is found to have no cauſticity, and to be nearly a pure calx of mercury. This is the ſubſtance known under the name of turbith mineral. The water, which has been poured on the vitriolic mercurial maſs, is found to contain a conſiderable quantity of vitriolic acid united to the calx of mercury.

The nitrous acid is decompoſed by mercury with the greateſt rapidity. Strong nitrous acid will take up its own weight of mercury in the cold, and this ſolution will bear to be diluted with water. If the ſolution is made by the aſſiſtance of heat, a much larger quantity is diſſolved; but a precipitate is produced by the addition of water. If cold water is employed, a white precipitate is afforded, but if hot water the precipitate is of a yellow colour, and greatly reſembles the turbith mineral produced by the vitriolic acid. If acid is added to the ſolution produced by heat, it is not decompoſed by water. This ſolution is very ponderous and acrid, and ſtains the ſkin of a deep purple, inclining in appearance to black, a portion of the mercury being precipitated by the animal matter, while the acid acts on it. Cauſtic alkali, added to this ſolution, precipitates a pure calx; mild alkali, a calx combined with carbonic acid. The volatile alkali precipitates the mercury in the form of a dark grey powder. When this precipitate is examined, it is found to contain a quantity of mercury in its metallic ſtate. If this matter is dried and rubbed on pure gold, it turns white, by which we may diſcover ſmall quantities of mercury in the metallic ſtate. The near approach to the metallic ſtate, obſerved in the precipitate afforded by the volatile alkali, ſeems to be owing to the preſence of hydrogen, which is one of the conſtituent principles of volatile alkali, and which has a ſtrong attraction for oxygen.

The precipitates of mercury, formed by alkaline intermediums, have a property diſcovered by M. Bayen, which muſt not be paſſed over in ſilence. They detonate like gun-powder, when expoſed in an iron ſpoon to a gradual heat, after having been triturated in the quantity of half a drachm, with ſix grains of flowers of ſulphur: after the detonation, a violet powder remains, which may be ſublimed into cinnabar.

The nitrous acid may be ſeparated from mercury by heat alone. Its firſt effect is to evaporate the watery parts; after this the acid flies off in deep coloured fumes; as the acid evaporates the calx becomes yellow, then of a deep red, but when removed ſome time, orange. This is the red precipitate of the ſhops. The nitrous acid, therefore, as in the caſe of other metals, though it acts with more rapidity, adheres with leſs force to the mercury than the vitriolic acid, which acts ſlowly and with difficulty. This proceeds, as was before mentioned, from the eaſe with which the nitrous acid is decompoſed, ſo as to afford to metals the oxygen which is neceſſary to render them ſoluble.

The muriatic acid has no action on mercury in its metallic ſtate, becauſe it cannot part with the oxygen neceſſary to calcine the metal. It has, notwithſtanding, a very ſtrong attraction for mercury, and diſſolves it with great readineſs when the latter is previouſly reduced to the ſtate of a calx. If a ſmall quantity of muriatic acid is poured on a nitrous ſolution of mercury, it ſeizes the metal, and forms a ſalt, which is precipitated in the form of a whitiſh coagulum, which, when dried, is called white precipitate, and is a kind of corroſive ſublimate. The marine ſalts, with baſe of alkali, or of any ſaline terreſtrial ſubſtance, ſuch as lime, magneſia, &c. produce the ſame effect, except that in this caſe, though the precipitate is the ſame, the nitrous acid, inſtead of being left uncombined, unites with the baſis of the marine ſalt which was employed.

If mercury, corroded by the vitriolic or nitrous acids, and dried, is mixed with powdered ſea ſalt, and expoſed to heat, a double attraction takes place; the nitrous or vitriolic acid deſerts the metal to unite with the fixed alkali of the common ſalt, while the muriatic acid ſeizes upon the mercury, and forms a metallic ſalt, which, in the degree of heat neceſſary for the operation, proves volatile, and, riſing in vapour, is condenſed in a ſolid form in the upper and cool part of the veſſel employed. This is the hydrargyrus muriatus, or corroſive ſublimate, which is a very acrid and powerful preparation of mercury.

The mild preparation, called calomel, is obtained by rubbing three parts of mercury, in its metallic ſtate, with four of corroſive ſublimate, till they form a greyiſh powder; the maſs is then ſublimed*, and forms a ſubſtance like corroſive ſublimate, but more ponderous, and of a more ſilvery appearance. The ingredients, however, are not ſufficiently mixed by the firſt ſublimation; they muſt be rubbed together again and ſublimed; and theſe proceſſes muſt be repeated at leaſt three times.

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* Made volatile, or raiſed in vapour, by the application of heat.

The converſion of the corroſive ſublimate into the milder ſubſtance, calomel, may be explained on the following principles:—In the corroſive ſublimate, the muriatic acid is found to be combined with a very large quantity of oxygen, which renders it extremely active. By the addition of mercury, a quantity of this ſuperfluous oxygen is abſtracted, for the calcination of the additional metal; and the whole maſs, therefore, contains the acid not only in a milder ſtate, but the ſame quantity of acid is diffuſed through a larger maſs of the metal.

Ponderous earth, magneſia, and lime, decompoſe the corroſive ſublimate, and precipitate a mercurial calx. The phagedenic water, made uſe of as a corroſive by ſurgeons, is made by throwing half a drachm of corroſive ſublimate, in powder, into a pound of lime water; a yellow precipitate is then formed, which renders the liquor turbid.

Acids and neutral alkaline ſalts produce no change on corroſive ſublimate, but it contracts an intimate union with ſal ammoniac without decompoſition. The ſal ammoniac renders corroſive ſublimate very ſoluble. The calx hydrargyri alba of the London Pharmacopeia is obtained from this combination. A quantity of ſal ammoniac is diſſolved in diſtilled water; an equal weight of corroſive ſublimate is then added; when this is diſſolved, fixed vegetable alkali is added, which produces a white precipitate. In this operation the fixed alkali diſengages the volatile alkali of the ſal ammoniac, which precipitates the mercury in the form of a white calx. This preparation is chiefly uſed in liniments externally. It is ſometimes adulterated with ceruſe, as the red precipitate is with minium. The fraud may be diſcovered by expoſing a ſmall quantity to heat in a ſpoon; if pure they will be entirely diſſipated, but if they contain lead, or other impurities, theſe matters will remain behind.

If the ſalt formed by the combination of acetous acid with the fixed vegetable alkali, commonly called regenerated tartar, or kali acetatum, is added to the ſolution of quickſilver in the nitrous acid, a double exchange takes place; the alkali unites with the nitrous acid, while the acetous acid enters into combination with the mercury, and is precipitated. This precipitate (being purified by ſolution in hot diſtilled water and filtration) has nearly the ſame medical properties as calomel, and is ſaid to form the baſis of Keyſer's pills. The acetous acid does not act on mercury unleſs when reduced to the ſtate of a calx.

As mercury is commonly, in a ſtate of nature, combined with ſulphur, ſo it may be artificially united to it with great eaſe. When one part of this metallic fluid is triturated with three parts of flowers of ſulphur, the mercury gradually loſes its metallic appearance, and is converted, by its union with the ſulphur, into a black powder, called Ethiop's mineral. This combination is more quickly effected by mixing the mercury with melted ſulphur. When this compound is expoſed to a conſiderable degree of heat it takes fire, the greater part of the ſulphur burns, and after the combuſtion a matter remains, which, when pulverized, is of a violet colour. To convert this powder into cinnabar it is put into matraſſes *, which are heated till their bottoms become red, and kept in this ſtate for ſeveral hours, till it appears that the matter is entirely ſublimed. The Dutch prepare, in the large way, the cinnabar employed in the arts. When much divided by levigation † it has a brilliant red colour, and is called vermilion.

Mercury has the property of uniting itſelf to many of the metals, by penetrating their ſubſtance, and rendering them more or leſs ſoft, according to the proportion of mercury employed. If the proportion of quickſilver is very great, the mixture is like quickſilver, and is only diſtinguiſhed from it by an appearance of foulneſs. If a ſmaller quantity is uſed, the maſs is ſoft like butter; if ſtill leſs, it is ſolid but brittle. Theſe mixtures are called amalgams. It readily combines in this way with gold, ſilver, lead, tin, biſmuth, and zinc, but not eaſily with arſenic and copper, and ſcarcely at all with iron, platina, nickel, or cobalt. Its action on the other metallic bodies has not been aſcertained.

A piece of gold, being rubbed with quickſilver, is ſoon penetrated by it, and is rendered ſo fragile

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* Veſſels uſed in chemical operations, of glaſs or earthenware, generally of the ſhape of an egg, and open at the top, the necks are long or ſhort, as occaſion may require.

† Reduced to a fine powder.

that it may be eaſily broken. A gold ring, which has become ſo tight on the finger that it cannot be drawn off, may be eaſily removed in this manner. Gold, united with quickſilver in certain proportions, forms a kind of paſte. On this property is founded the proceſs of gilding in *or moulu*. A ſmall quantity of this paſte is ſpread upon the ſurface of the copper which is to be gilded in *or moulu*, and the metal is then expoſed to heat. Quickſilver evaporates in a far leſs degree of heat than is ſufficient to melt either gold or copper; when, therefore, the mixture of gold and quickſilver is expoſed to heat, the quickſilver is driven off in vapour; but the gold, not being ſuſceptible of evaporation, remains attached to the ſurface of the copper, and undergoing the operations of burniſhing, &c. the latter is gilded, or gilt. This method of gilding copper, by means of gold and quickſilver, was known to the Romans. The ſurface of iron cannot be covered in the ſame way with gold; but the iron, by being moiſtened with a ſolution of blue vitriol, as in the proceſs for browning firelocks, and being thus covered with a lamina of copper, becomes as ſuſceptible of being gilded as if its whole ſubſtance was copper.

It is this property which quickſilver has of uniting with the precious metals, and diſſolving them, which has rendered it ſo ſerviceable in the extraction of them from the earth with which they are mixed. The earth or ſtones, in which gold and ſilver are contained, being reduced to powder, are mixed with quickſilver, which diſſolves every particle of the precious metals without contracting the leaſt union with the other matters; the quickſilver is then driven off by heat, and, being condenſed in the receiver, is again employed in the ſame proceſs. The gold and ſilver are ſeparated from each other by proceſſes, which will be deſcribed in treating of thoſe metals. Since the diſcovery of the American gold mines, the conſumption of quickſilver has been much increaſed. Hoffman concludes, from calculation, that fifty times as much gold as quickſilver is annually extracted from the bowels of the earth.

Looking glaſſes are covered on one ſide with an amalgam of tin and mercury. Tin, being beaten into thin leaves, is called tin foil; on tin foil, evenly diſpoſed on a flat ſtone, quickſilver is poured, and ſpread with a feather until its union has brightened every part of it; a plate of glaſs is then cautiouſly ſlid upon the tin foil, in ſuch a manner as to ſweep off the redundant quickſilver which is not united to the tin; weights are then placed on the glaſs ſo as to preſs out ſtill more of the quickſilver, and in a little time the tin foil, thus united to the quickſilver, adheres ſo firmly to the glaſs that the weights may be removed without any danger of its falling off. About two ounces of quickſilver are uſed in covering three ſquare feet of glaſs.

In order to make mercury capable of acting on the animal body, it is neceſſary that it ſhould undergo ſome preparation; for its particles muſt be very minutely divided before they can enter the veſſels. Thus, if we apply quickſilver to a capillary tube, the attraction of its particles for each other is ſo ſtrong that they will not riſe in it; but minute diviſion is not the only circumſtance neceſſary to its activity, for Ethiop's mineral and cinnabar taken into the body have very little if any effect. Oxygenation ſeems to be the moſt eſſential circumſtance; for in whatever way this is effected the mercury becomes very active*.

Mercury, in paſſing through the body, is reduced to the metallic ſtate, and, exuding through the pores, ſometimes attaches itſelf to the gold of watches, rings, ſleeve-buttons, or ear-rings, and renders them white.

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* Does not the effect of ſulphur, in diminiſhing the activity of mercurial preparations, depend on its ſuperior attraction for oxygen, by which it has a tendency to reduce the mercury to the metallic ſtate?

CHAP. XXXII.

SILVER.

Character of the perfect Metals.—General Properties of Silver.—Vegetation of Silver.—Natural Hiſtory of Silver.—Aſſaying of Silver.—Cupellation.—Lunar Cauſtic.—Fulminating Silver.—Luna Cornea.—Diana's Tree.—Green Gold.—Standard Silver Coin.—Plating with Silver; how performed.—French Plate.

OF the different metallic ſubſtances only three have been dignified by chemiſts and mineralogiſts with the appellation of perfect, viz. ſilver, gold, and platina. Theſe are diſtinguiſhed from the other metals by their weak attraction for oxygen, which enables them to retain their purity and metallic ſplendor in ſituations in which other metals become gradually covered with ruſt or calx. Silver is the whiteſt of all metals, and is poſſeſſed of great brilliancy; it is harder than gold; in weight it is exceeded by gold, platina, quickſilver, and lead; its gravity being only about ten times that of water. Its malleability is ſo great, that a grain of it reduced to ordinary ſilver leaf meaſures about fifty-one ſquare inches, in which ſtate it is not more than the hundred and ſixty thouſandth part of an inch thick, which, however, is conſiderably more than one third thicker than gold leaf. Its tenacity is ſo conſiderable, that it may be drawn into wire about half the thickneſs of a fine human hair, and a wire of one tenth of an inch in diameter will ſupport the weight of two hundred and ſeventy pounds without breaking. It is very ſonorous, but in hardneſs and elaſticity it is not equal to copper. It hardens under the hammer, but very readily loſes that hardneſs by heating.

Silver, expoſed to the heat of the moſt powerful burning lenſes, is partly vitrified and partly volatilized in fumes, which are found, when received on a plate of gold, to be ſilver in the metallic ſtate. It is likewiſe ſaid to have been partly calcined by twenty ſucceſſive expoſures to the heat of the porcelain furnace at Sêves. This, however, may be doubted, as ſilver does not undergo any degree of calcination by expoſure to heat, even with the addition of nitre. Silver melts in the firſt degree of white heat, and appears in the fire like the fineſt quickſilver. When it is haſtily cooled, it exhibits a curious phenomenon, called vegetation; for we diſcover from different parts of its ſurface ramifications and branches like thoſe of trees which ſprout out with a ſtem. The reaſon of this appearance ſeems to be the irregular contraction which the ſilver undergoes in paſſing from the fluid to the ſolid ſtate. The melted ſilver ſuffers the firſt commencement of congelation at its ſurface; by theſe means a cruſt is formed, which by its ſudden contraction compreſſes the fluid ſilver within; thus a protuberance is formed, which, congealing in its turn, contracts and preſſes the intermediate fluid through its cruſt into branches.

The air alters ſilver very little, unleſs it contains ſulphureous vapours, which it often does, from the putrefaction of animal ſubſtances or the exhalations of drains, or of ſulphureous mineral waters. This metal, therefore, becomes ſomewhat tarniſhed by long continued expoſure to the atmoſphere, and in time becomes covered with a thin purple or black coating, which, after a long ſeries of years, has been obſerved to ſcale off from images of ſilver expoſed in churches, and was found, on examination, to conſiſt of ſilver united to ſulphur.

Silver is often found in its native ſtate, and may be known by its brilliancy and ductility. It is ſometimes met with in irregular maſſes, ſometimes it the form of capillary threads or fibres, and ſometimes in that of branches, formed by octahedrons inſerted one into the other. It is alſo often diſperſed in a quartzoſe gangue.* Native ſilver is ſometimes found alloyed with gold, copper, iron, or regulus of antimony; but native gold much oftener contains ſilver than native ſilver does gold. Silver is not naturally found in the ſtate of calx.

The vitreous ore of ſilver is compoſed of that metal and ſulphur. It is the richeſt of the ſilver ores, and yields from ſeventy to eighty pounds of the metal in the hundred weight. It is of a blackiſh grey colour, reſembling lead; ſome ſpecimens are brown, greeniſh, yellow, &c.; it may be cut with a knife, and is ſometimes cryſtallized. If it is expoſed to a heat not ſufficient to melt it, the ſulphur is diſſipated, and the virgin ſilver is obtained in fibres.

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* A quartzoze or ſparry cryſtallization, often found incloſing the ores of metals, and therefore called the matrix or rider.

The red ſilver ore contains arſenic as well as ſulphur. It is a heavy ſhining ſubſtance, ſometimes tranſparent, ſometimes opake, but commonly cryſtallized. It is often of a deep red colour on the outſide, but appears paler within. It affords about half its weight of ſilver. If it is expoſed to a fire carefully managed, and capable of igniting it, the ſilver is reduced, and forms capillary fibres, ſimilar to native ſilver.

There is a ſilver ore containing arſenic, cobalt, and iron, mineralized by ſulphur. This ore ſometimes yields half its weight of ſilver; it varies in its appearance, being ſometimes of a grey and brilliant aſpect, but often of a dull and tarniſhed colour, with efflореſcences of cobalt. The gooſe dung ore belongs to this ſpecies. The grey ore of ſilver contains a large quantity of copper. The black ſilver ore, called nigrillo by the Spaniards, ſeems to be a middle ſtate between native ſilver and ſome of its ores, or thoſe ores in a ſtate of imperfect decompoſition. The corneous ſilver ore is a natural combination of ſilver and muriatic acid with a ſmall quantity of vitriolic acid. Silver is alſo found in conſiderable quantity in the ores of other metals, particularly thoſe of antimony, zinc, lead, and copper.

In the aſſaying of ſilver ores different proceſſes are uſed, according to their nature. When found in its metallic ſtate, nothing more is neceſſary than to ſeparate it from the earthy or ſtony matter in which it is embedded. With this view it is firſt expoſed to heat, to render the ſtony matter friable.

The maſs is then mixed and ground with quickſilver. Thus the ſilver is converted into an amalgam, which, from the intimate union of the particles of the metals, is ſpecifically heavier than quickſilver itſelf. The ſtony matters are now eaſily waſhed off, without loſing any of the metal. The quickſilver is afterwards partly ſeparated by ſqueezing it through a piece of leather, and the remainder by diſtillation. Sulphureous ſilver ores require to be firſt roaſted, and then mixed with a quantity of flux. In order to ſeparate lead, copper, iron, &c. from ſilver, a particular proceſs is employed, which is called cupellation, from the veſſel in which it is performed, called a cupel, and which is chiefly formed of calcined bones, and is very porous. The metallic maſs containing ſilver is mixed with a conſiderable quantity of lead, and then expoſed on the cupel in a ſtate of fuſion. The lead is vitrified and abſorbed into the cupel, carrying with it the imperfect metals, and the ſilver remains behind on the cupel in a pure ſtate.

The vitriolic acid acts on ſilver as on the other metals, with the aſſiſtance of heat; it then corrodes it into a white maſs, which is ſoluble in water, and by evaporation affords ſmall cryſtals.

The nitrous acid diſſolves ſilver with great rapidity. When the ſtrong nitrous acid is diluted with an equal weight of water, it is capable of diſſolving about half its weight of ſilver. If the ſilver employed is quite pure, the ſolution is limpid like water; but as ſilver commonly contains a little copper, its ſolutions have uſually a blueiſh tinge.

If the ſilver employed contains gold, in this caſe, as the nitrous acid is not capable of diſſolving the gold, it ſeparates from the ſilver in the form of blackiſh flocks. From this difference in the action of nitrous acid on ſilver and gold, it is ſucceſsfully uſed to ſeparate theſe metals from each other.

The ſolution of ſilver in the nitrous acid is extremely bitter and cauſtic, and has the property of changing the ſkin or hair to a black colour, or, if very much diluted, to a brown, and formerly, when the caprice of faſhion abhorred light hair as much as it at preſent admires it, was employed for that purpoſe. The colour is, however, very faint when the ſolution is firſt applied, and the production of colour ſeems in a great meaſure to depend on the action of light. Dr. Lewis mentions a remarkable phenomenon, which this ſolution preſents when added to chalk or any pure abſorbent earth. The chalk and ſolution are both at firſt quite white, and will continue ſo if kept in a dark place, but if expoſed to the light they ſoon become black; ſo that if a quantity of this mixture is put into a glaſs phial ſealed up, any marks or letters may be made to appear on it as if by magic. To effect this, the phial is covered with thick paper, in which the marks or letters are nicely cut, and it is then expoſed to the light, which, acting only through the apertures of the paper, produces the effect. When the ſtains are produced, aqua fortis, by re-diſſolving the ſilver, will make them diſappear again. It therefore ſeems, that the production of colour is owing to an imperfect reduction of the ſilver, and that the action of light diſengages oxygen from this compound in the ſame manner as it does from the pale nitrous acid, and from vegetables.

When this ſolution of ſilver is evaporated with a gentle heat, it may be made to afford cryſtals nearly reſembling thoſe of nitre. Theſe, being melted in a crucible, are freed from water, and being poured into moulds of a convenient form, become the ſilver or *lunar* * cauſtic, or argentum nitratum of the pharmacopœia.

Silver is never given internally, and this is the only preparation of it made uſe of externally. The nitrous acid may be entirely ſeparated from this compound by heat alone.

Silver, however, is moſt conveniently ſeparated from its nitrous ſolution by immerſing plates of copper in it. The copper is then diſſolved, while the ſilver is depoſited in its metallic ſtate. This metal may be ſeparated from gold by expoſing the mixed metals to the action of nitrous acid, which diſſolves the ſilver and leaves the gold, and the above method is uſed to obtain the ſilver from the acid.

To make the famous fulminating ſilver, which is ſo truly formidable in its effects, a ſmall quantity of ſilver is diſſolved in pale nitrous acid (or aqua fortis) from which it is precipitated by lime water. The calx or precipitate is to be dried by expoſure to the air for three days. The inventor, M. Bertholet, ſuppoſes the action of light to have alſo ſome influence in the ſucceſs of the experiment*. The dried calx is then agitated in a ſolution of the cauſtic volatile alkali, when it aſſumes the form of a black powder, which is left to dry in the open air. The fulminating ſilver then conſiſts of an union of the calx of ſilver with volatile alkali.

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* A name taken from the whim of the alchemiſts, who called the metals by the names of the heavenly bodies: gold, Sol; ſilver, Luna; copper, Venus; iron, Mars (whence martial vitriol, &c.); lead, Saturn; tin, Jupiter; quickſilver, Mercury, &c.

The effects of this preparation are tremendous, and infinitely exceed thoſe of gunpowder, fulminating powder, or fulminating gold. It explodes with the ſlighteſt agitation or friction. The falling of a few atoms of it from a moderate height produces a violent detonation, and a drop of water falling upon it has the ſame effect. When it is once fully prepared, it muſt not be touched or moved into any other veſſel, but muſt remain in that in which it was dried; and to make the experiment with tolerable ſafety, not more than a grain of ſilver ſhould be employed in the proceſs. The cauſe of theſe exploſions has been already intimated in the chapter on ignition, and will be further illuſtrated in treating of fulminating gold.

Though the nitrous acid diſſolves ſilver with greater eaſe, it has not ſo ſtrong an attraction for it as the muriatic or vitriolic acids. Either of theſe, dropped into the nitrous ſolution, ſeize the ſilver, and forming a compound not equally ſoluble produce a precipitation. The neutral ſalts, containing vitriolic or muriatic acid, have the ſame effect. This difference of affinity between the acids and ſilver is the foundation of a proceſs for obtaining the nitrous acid in a ſtate of great purity. The ſolution of ſilver in nitrous acid is poured into the impure nitrous acid till no more precipitate is formed. The muriatic or vitriolic acids contained in the mixture are thus carried to the bottom by their union with the ſilver. The acid is then decanted and diſtilled to free it from the ſmall quantity of ſalt of ſilver which it may ſtill contain.

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* Journal de Phyſique for June 1788, p. 474.

Notwithſtanding the muriatic acid has the ſtrongeſt affinity with ſilver of all the acids, it is nevertheleſs incapable of diſſolving it unleſs the metal is in a calcined ſtate, or itſelf ſuperoxygenated. The common method of effecting this union is to add to the ſolution of ſilver, in the nitrous acid, any ſaline ſubſtance which contains the muriatic acid; it is no matter to what the acid is joined, whether alkali, earth, or metal; it immediately ſeizes the ſilver, and leaves the other matter to unite with the nitrous acid. Common ſalt is generally uſed, and the white precipitate, which is immediately formed, has the appearance of a coagulum. The compound thus made is ſo inſoluble in water, that there cannot be a nicer teſt of the preſence of the muriatic acid, or common ſalt, in waters, than the nitrous ſolution of ſilver; for if the moſt minute quantity of either are preſent a precipitation is produced.

This compound has many other qualities beſides inſolubility in water. If we collect it, and waſh off the ſaline matter, it appears as a fine powder, and, when heated to a ſufficient degree, melts into a ſubſtance of ſome tranſparency. From its tranſparency, flexibility, and ſoftneſs, it is called *luna cornea*, or *argentum corneum*, and from this ſeveral other compounds of metals with the muriatic acid have been called *cornea*. It may be cut into tranſparent veſſels reſembling glaſs.

Aqua regia, or the compound of nitrous and muriatic acids, acts ſtrongly on ſilver, but forms a precipitation in proportion as it ſeparates it from the maſs. This effect may be readily underſtood from what has already been obſerved. The nitrous acid diſſolves the ſilver, and the muriatic ſeizes it, and forms *luna cornea*, which is inſoluble. This proceſs may be uſed to ſeparate gold from ſilver; the gold is held diſſolved in the aqua regia, but the ſilver is precipitated.

After ſilver has been reduced to the calciform ſtate by ſolution in nitrous acid, and precipitation by alkalies, it is capable of ſolution in vinegar, and even in lemon juice; but theſe compounds have not been applied to any uſe.

To have ſilver perfectly pure we muſt uſe quickſilver, which, if poured into a ſolution of ſilver, is attracted by the acid, and precipitates an amalgam with the ſilver at the bottom of the veſſel. The quickſilver is eaſily ſeparated from the ſilver by heat alone. A curious phenomenon ariſes from this amalgam; a kind of cryſtallization takes place, which is formed by the union of the ſilver with the running mercury. The amalgam puts forth ſhoots, which afterwards put forth others, like the branches of a tree. The cryſtallization varies according to the conduct of the proceſs, and does not always anſwer, particularly if the mixture is ſhaken. It is called *arbor Dianæ*, or Diana's tree *. The method of making it moſt beautiful is very tedious, and would require the ſpace of a month.

This phenomenon ſeems to admit of explanation preciſely on the ſame principle as the branching of pure ſilver when paſſing from its fluid to its ſolid ſtate. The amalgam of ſilver and mercury is ſpecifically heavier than either of the metals in a ſeparate ſtate, and their union muſt conſequently be attended with contraction. The ſilver, therefore, being precipitated on the ſurface of the mercury, in proportion as the latter metal is diſſolved by its ſuperior attraction for the acid, the mercury becomes ſurrounded with a cruſt, the contraction of which forces out its fluid contents; the excreſcences thus produced being in their turn covered with a cruſt of amalgam, are again compreſſed, and produce ſmaller protuberances, and if the experiment is properly conducted, the brittle amalgam of the metals aſſumes a cryſtallized appearance, and the form of a thick buſh. In this experiment it is neceſſary that there ſhould be not only as much mercury as is ſufficient to precipitate the ſilver, but beſides this a quantity remaining in its fluid ſtate, to unite with the precipitated ſilver into an amalgam.

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* Diana's tree, from the whim of the alchemiſts already noticed, who appropriated ſilver to the Moon or Diana, as ſtated in a preceding note.

Sulphur has a remarkably ſtrong affinity with ſilver, and forms with it a compound which has the appearance and ſoftneſs of lead. This metal ſeems alſo capable of attracting ſulphur from antimony. But though ſilver has ſo ſtrong an attraction for ſulphur, gold has none, and this furniſhes a method of ſeparating theſe metals by fuſion.

With gold, ſilver forms a pale alloy, the green gold of the jewellers and gold beaters. This mixture, however, is not made without ſome difficulty, on account of the different ſpecific gravities of the two metals. It does not unite well with platina. It forms an alloy with iron, but the properties of it have not been well examined into. With lead it forms an alloy, which is much more fuſible than pure ſilver, and ſeems in all reſpects to be of an intermediate nature between theſe metals. Copper increaſes the hardneſs of ſilver, and renders it more ſonorous, without impairing its ductility or colour, when the copper does not exceed the twelfth part of the weight of ſilver employed. The ſtandard of ſilver coin is eleven ounces two pennyweights, troy, of ſilver, and eighteen pennyweights of copper.

The purity of ſilver cannot be accurately aſcertained without ſubmitting it to cupellation with lead, and its purity is calculated according to the weight it loſes in that proceſs. Silver is divided into twelve imaginary parts, called pennyweights. If it only loſes one twelfth part of its weight by cupellation, it contains eleven twelfths of pure ſilver,

ver, and is ſaid to be eleven pennyweights fine; if it loſes two twelfths, it is ten pennyweights fine, and ſo of other proportions. For greater accuracy, each pennyweight is ſuppoſed to be divided into twenty-four grains.

The covering of the ſurface of copper with ſilver, or plating, is performed in the following manner: ‘ Upon ſmall ingots of copper, plates of ſilver are bound with iron wire, generally allowing one ounce of ſilver to twelve ounces of copper. The ſurface of the plate of ſilver is not quite ſo large as that of the copper ingot. Upon the edges of the copper, which are not covered by the ſilver, a little borax is put, and by expoſing the whole to a ſtrong heat, the borax melts, and in melting contributes to melt that part of the ſilver to which it is contiguous, and to attach it in that melted ſtate to the copper. The ingot, with its ſilver plate, is then rolled under ſteel rollers, moved by a water wheel, till it is of a certain thickneſs; it is afterwards rolled by hand rollers to a greater or leſs extent, according to the uſe for which it is intended; the thinneſt is applied to the lining of drinking horns. An ounce of ſilver is often rolled out into a ſurface of about three ſquare feet, and its thickneſs is about the three thouſandth part of an inch; and hence we need not wonder at the ſilver being ſoon worn off from the ſharp angles of plated copper, when it is rolled to ſo great an extent.

‘ What is commonly called French plate is not to be confounded with the plated copper. In making French plate, copper, or, more commonly, braſs, is heated to a certain degree, and ſilver leaf is applied upon the heated metal, to which it adheres, by being rubbed with a proper burniſher*.'

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[*] Watſon's Chemical Eſſays.

CHAP. XXXIII.

GOLD.

General Properties of Gold.—Gold calcined by Electricity.—Extreme Ductility of this Metal.—Natural Hiſtory of Gold.—Proceſſes for ſeparating Gold from other Subſtances.—Quartation.—The Touchſtone.—Aqua Regia.—Reaſons why the different Acids act on metallic Bodies.—Fulminating Gold.—Purple Powder of Caſſius.—Golden Calf, how deſtroyed by Moſes.—Union of Gold with other Metals.—Standard Gold Coin of different Countries.

GOLD is the heavieſt of all the metals except platina, being between nineteen and twenty times the weight of water. When perfectly pure it is almoſt as ſoft as lead, and is neither elaſtic nor ſonorous. For its fuſion it requires rather more heat than ſilver, and when in fuſion has a blueiſh green colour, and its ſurface is always perfectly bright. The moſt intenſe heat cannot calcine it, and only contributes to render it more pure if it had any foulneſs. The powerful burning mirrors are ſaid to have volatilized it, and it has been driven up in fumes, in the metallic ſtate, by flame urged upon it by a ſtream of vital air. The electric fluid, however, when made to paſs in conſiderable quantities through gold leaf, incloſed between two plates of glaſs, converts it into a calx, which tinges the glaſs of a purple colour.

The tenacity of gold is ſo great, that a wire one-tenth of an inch in diameter is capable of ſupporting five hundred pounds. Its malleability and ductility exceed thoſe of ſilver, and are ſo remarkable, that their limits could never be aſcertained with any conſiderable exactneſs. On gold lace the thickneſs of the gold has been computed to be leſs than the one hundred and thirty-four thouſandth part of an inch, and the degree of extenſibility has been carried ſtill farther. In ordinary gold-leaf, which is made by hammering plates of gold between ſkins, or animal membranes, a grain is made to cover fifty-ſix ſquare inches and a quarter. In this ſtate its ſurface is ſo great that it may be made to float in the air with the ſlighteſt agitation, and its thickneſs is not more than the two hundred and eighty-two thouſandth part of an inch.

Gold is produced by nature very plentifully. There is much of it in Brazil, in the Spaniſh Eaſt and Weſt Indies, on the coaſt of Africa, and in Upper Hungary, where the mines have remained unexhauſted for ten centuries. Peru and Mexico abound with gold in a variety of forms. It is met with in the ſands of rivers and mountains. Some rivers in France, as well as in this country, contain gold in their ſand. It is alſo found in the fiſſures of rocks, imbedded in hard ſtones. Pieces of gold of ſeveral ounces, and even pounds weight, are ſometimes found, but in general it is diffuſed in ſo ſmall portions, and through ſo large a quantity of ſand, that the trouble of extracting it is ſcarcely repaid by the gains. In all parts of the world, particularly in Europe, gold is moſt frequently found in ſtrata of ſand, in which it ſeems to have been depoſited by water. Gold mines were once wrought in Scotland, and it appears upon record that forty-eight thouſand pounds ſterling of this gold was coined in the Scotch mint. It is now a general opinion among mineralogiſts, that there are ſcarcely any ſands entirely free from gold, and which, by accurate examination, cannot be made to afford more or leſs of that ſubſtance.

Conſidering that gold has no attraction for ſulphur, and very little for arſenic, which are the uſual mineralizers of metallic bodies, it is not ſurprizing that it ſhould be uſually found in a ſeparate and nearly pure ſtate. The metallic bodies, with which it is alloyed in a ſtate of nature, ſeldom conſtitute any conſiderable part of its weight; they are generally either ſilver, copper, or iron. Gold, however, is ſometimes mixed with martial pyrites, and is ſometimes contained in an ore, which is a mixture of lead, ſilver, and iron, mineralized by ſulphur. In theſe caſes the preſence of gold is not known by the appearance of the mineral, and can only be diſcovered by roaſting, and ſubſequent fuſion with ſuch matters as are capable of vitrifying the earthy and martial ſubſtances. The addition of lead is alſo uſeful, which unites with the gold, and carries it to the bottom of the maſs. The gold is eaſily obtained free from the lead by the proceſs of cupellation.

In order to ſeparate gold, when in its native ſtate, from the earthy and ſtony matters in which it is contained, the following proceſs is employed: When it is contained in ſand, the lighter particles of the latter are waſhed away by water, and the remaining matter, which may prove ſo heavy as not to be ſeparated from the gold without danger of loſing ſome of the precious metal, are amalgamized, by being ground with mercury, in the ſame manner as has been mentioned in the extraction of ſilver. If the gold is mixed with ſtones of conſiderable bulk, it is neceſſary that they ſhould be reduced to powder in order to render them ſufficiently light to be waſhed away. The mercury is alſo ſeparated from gold in the ſame way as from ſilver; as much as poſſible is ſeparated from it by preſſure in bags of leather, and the remainder by heat.

All the imperfect metals may be abſtracted from gold by cupellation; but in order to ſeparate ſilver from it, other proceſſes muſt be employed. The beſt of theſe is called quartation, becauſe the gold muſt not exceed the *fourth* part of the weight of the maſs ſubmitted to trial. The gold, therefore, muſt be firſt mixed with three times its weight of ſilver, the effect of which is, that the particles of gold are removed to ſuch a diſtance that they cannot protect the ſilver from being acted on. The maſs of gold and ſilver being then beaten out into thin plates to increaſe the ſurface, are expoſed to the action of aqua fortis, which diſſolves the ſilver, and leaves the gold in a ſpongy maſs; this is waſhed two or three times with aqua fortis, and then expoſed to heat in a muffle *, to recover its metallic brightneſs. When ſilver is thus ſeparated by aqua fortis, a minute portion of the ſilver is apt to adhere to the gold, and, therefore, when it is an object to have the gold perfectly pure, it is proper to ſubmit it to the action of aqua regia, which diſſolves the gold, and converts the ſilver into luna cornea, which is precipitated to the bottom of the veſſel. When it is intended to ſeparate ſilver by aqua regia, the proportions of the metals muſt be reverſed, and as the gold is to be diſſolved, it muſt be three times the weight of the ſilver.

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* A ſmall earthen oven made and ſold by the crucible manufacturers.

In this way gold may be obtained quite pure; but the goldſmiths find a difficulty in obtaining it perfectly ductile. To have it ſoft and tough it muſt be melted with a ſtrong heat, and afterwards cooled very ſlowly.

In applying ſaline ſubſtances to gold, it is found that none of the acids, ſeparately employed, either in a fluid form or in that of hot vapours, produce the leaſt effect on it in its metallic ſtate. Upon this depends the trial of gold by the lapis lydius, or touchſtone, which is of a dark colour and pretty fine grain, but when poliſhed has ſufficient roughneſs, ſo that when the metal is rubbed over it a mark is left, which mark will be affected by any of the common acids, aqua fortis for inſtance, in proportion to the impurities the metal contains, but not at all if the gold is perfectly pure.

Goldſmiths uſe likewiſe two ſets of needles, one for ſilver and the other for gold, when they want to examine the fineneſs of different parcels. The ſets of needles for gold are alloyed with different proportions of copper; one is made with twenty-three parts of gold to one of copper, another with twenty-two parts of gold to one of copper, and ſo in proportion. When they have a piece of gold to be tried, they firſt examine its colour to determine what quantity of alloy it contains. To know this the better, they mark the touchſtone with it, and then make another mark with the needle, which they think to be of nearly ſimilar purity. Thus they compare them; and after this, to be certain that the metal is gold, they apply to the mark on the ſtone a drop of aqua fortis. If it is copper tinged with zinc, or any other imitation of gold, the aqua fortis immediately diſſolves it. If it contains gold and ſome other metal, it diſſolves the other metal, and leaves the gold.

The only ſaline fluid which diſſolves gold in its metallic ſtate is aqua regia, or a mixture of the nitrous and muriatic acids. It is prepared various ways: 1ſt, By mixing the two acids in their pure ſtate. 2dly, By adding common ſalt, or ſal ammoniac, to aqua fortis, and then diſtilling the mixture. A part of the nitrous acid decompoſes the muriatic ſalt, and detaches the muriatic acid, which riſes with the remainder of the nitrous acid, and thus an aqua regia is produced. 3dly, By mixing a ſolution of alum with nitre and common ſalt, in which caſe the vitriolic acid of the alum diſengages the nitrous and muriatic acids by its ſuperior attraction for their baſes.

It is uſual to make aqua regia by diſſolving ſal ammoniac in about four times its weight of ſtrong nitrous acid; but the reſults of experiments or operations vary conſiderably according to the proportion of the ingredients made uſe of.

The theory of the operation of this compound acid does not ſeem difficult. In the courſe of this work it has been more than once remarked, that the eaſy ſolution of metallic matters in acids does not depend merely on the degree of attraction which exiſts between the metal and the acid, but alſo on the eaſe with which the acid parts with oxygen to calcine the metal. From this cauſe it happens, that the nitrous acid, which has much leſs affinity with metallic matters than the vitriolic or muriatic, diſſolves them more readily than either of theſe. Aqua regia, however, conſiſts of the acid which has the ſtrongeſt attraction for metallic bodies, and alſo of that which moſt eaſily parts with oxygen, and the union of theſe powers produces the effect of ſolution. That this is the true explanation of the ſolution of gold in aqua regia appears from ſeveral circumſtances; for gold, previouſly reduced to the ſtate of calx, that is, furniſhed already with a quantity of oxygen, is eaſily diſſolved by muriatic acid, and gold, in its metallic ſtate, is diſſolved by the oxygenated or aerated muriatic acid, and forms with it the ſame ſalt which is uſually obtained by the mixed acid, or aqua regia. The muriatic acid, therefore, is the true ſolvent of gold, and the addition of nitrous acid has no other effect than that of furniſhing oxygen, ſince the ſame effect follows when the neceſſary quantity of oxygen is previouſly added either to the gold or the muriatic acid. Gold, precipitated from aqua regia by alkalies, and thus reduced to the calciform ſtate, is ſoluble even in the vitriolic and nitrous acids.

The addition of water to the vitriolic acid enables it to diſſolve iron exactly on the ſame principle that the addition of nitrous acid to the muriatic enables the latter to diſſolve gold. The concentrated vitriolic acid has no action on iron without the aſſiſtance of heat; but by a proper addition of water the proceſs goes on, in the ordinary temperature of the atmoſphere, with conſiderable rapidity. The water furniſhes oxygen to the iron, and its other component part, hydrogen, is ſet at liberty; and that the nitrous acid, in the aqua regia, anſwers the purpoſe of furniſhing oxygen to the gold, is proved by the diſengagement of nitrous gas.

The ſolution of gold in aqua regia, when firſt made, is always yellow, conſiderably cauſtic, corrodes animal matters, and tinges them of a deep purple colour. When applied to the ſurface of marble, it tinges it of a violet colour. This colour is produced by a precipitation of the gold, in conſequence of the ſuperior attraction of the calcareous earth for the acid.

The ſolution of gold may be made, by cautious evaporation, to afford cryſtals of a beautiful topaz or yellow colour. Gold may be in ſome meaſure volatilized by repeatedly diſtilling it with aqua regia; ſome of the gold riſes with the acid into the neck of the retort in the form of long ſlender brown cryſtals.

Gold is precipitated from its ſolution by a great variety of ſubſtances, but its appearances are very various, according to the nature of the matter employed. Lime and magneſia precipitate gold in the form of a yellowiſh powder, and the fixed alkalies have the ſame effect. Volatile alkali produces a more quick and copious precipitation, and forms the remarkable compound, known by the name of aurum fulminans, the nature of which has been already intimated in a note under the head of ignition. I ſhall in this place, however, add a few obſervations, which may tend ſtill further to illuſtrate its nature. In the firſt place, it appears that the fulminating gold is a compound of about three parts of that metal with one of volatile alkali. Secondly, Fulminating gold, expoſed to ſuch a heat as is ſufficient to ſeparate the volatile alkali, without ſetting fire to the compound, loſes its fulminating property. The ſame effect is produced by ſubmitting the aurum fulminans to the action of concentrated vitriolic acid, melted ſulphur, æther, or any ſubſtance capable of abſtracting the volatile alkali by ſuperior affinity. Thirdly, When a few grains of aurum fulminans are detonated in copper tubes, the extremity of which is plunged beneath the mercury of the pneumato-chemical apparatus, azote is diſengaged, a few drops of water are produced, and the gold is reſtored to its metallic appearance. M. Berthollet, the inventor of this experiment, concludes, that the volatile alkali is decompoſed, and that while one of its component parts, hydrogen, unites with the oxygen of the calx of gold, and forms water, its other component part, azote, eſcapes in the form of gas. The readineſs with which fulminating gold explodes ſeems to depend on the tendency which the hydrogen of the alkali has to unite with the oxygen of the metallic calx, which tendency the weak attraction of the gold for the oxygen on the one hand, and the azote for hydrogen on the other, are ſcarcely ſufficient to counteract. Whenever the balance of power among theſe ingredients is diſturbed, which happens from a moderate increaſe of heat, or violent friction, the hydrogen and oxygen unite and form water, the gold is reduced, and the azote eſcapes in the form of gas, occaſioning a violent exploſion.

When gold is newly precipitated, Margraff informs us, that it may be re-diſſolved by the volatile alkali, or, much more readily, by the Pruſſian alkali. Alkaline ſalts precipitate gold in the form of a calx, but inflammable ſubſtances precipitate it in the metallic form. The moſt ſingular effect of inflammable ſubſtances upon the ſolution of gold is that of the vitriolic æther, though it does not entirely ſeparate the gold from the acid. If into a phial of diſtilled water a ſingle drop of the ſolution of gold is introduced, the water will become of a fine yellow colour; add to this a quantity of vitriolic æther, which will float uppermoſt, and remain colourleſs, no ſenſible change being produced; by ſhaking the mixture, however, for ſome time, and then allowing it to reſt, the yellow colour in the loweſt part of the phial will leave the water, and riſe up into the æther.

By repeated agitation, in a little time the æther will draw up into it the whole of the gold, ſo as to leave the liquor at bottom perfectly colourleſs. It would be erroneous to conclude from this experiment, that æther is a ſolvent of gold; it does not diſſolve it, but attracts the ſolution merely by its affinity for acids. Though the æther acts primarily on the acid, it at length ſeparates the oxygen from the calcined gold, and precipitates it in its metallic ſtate. All the ſubtile aromatic oils have a ſimilar effect, but do not act ſo readily as æther.

As theſe inflammable fluids have no action on the ſolutions of other metals, this proceſs may be uſed as a means of refining gold; for the acid containing gold is imbibed by the inflammable fluid, while that part of it which is combined with any other metal remains behind.

Almoſt all metallic ſubſtances precipitate gold from its ſolution in aqua regia. Mercury and copper ſeparate it in its ſhining metallic form; lead, iron, and ſilver, precipitate it of a deep and dull purple colour. A plate of tin, plunged in a ſolution of gold, ſeparates the perfect metal in the form of a deep violet powder, called purple powder of Caſſius, which is uſed in painting, in enamel, and in porcelain. This powder conſiſts of the calces of gold and tin in combination, and is capable of communicating a fine purple colour to glaſs. The ſolution of green vitriol precipitates no other metal but gold, and the gold proves of uncommon purity, and of a very deep colour. Gold in its metallic ſtate is incapable of uniting with ſulphur alone, but if a piece of gold is dropped into a ſolution of hepar ſulphuris, eſpecially if the latter is prepared with equal parts of ſulphur and alkali, the gold diſſolves with ſome ebullition, and forms a maſs, which diſſolves in water like the combination of alkali and crude antimony.

Stahl ſuppoſes that this proceſs was uſed by Moſes to render the golden calf, adored by the Iſraelites, ſoluble in water.

But though gold will not unite with ſulphur, it may be purified by means of it, the ſulphur uniting with the metals with which it is alloyed. With this view it is uſual to heat the gold with crude antimony, in which ſtate the ſulphur is more fixed than when applied in a ſeparate ſtate. In this proceſs, however, the gold combines with a portion of antimony, which muſt be afterwards driven off by heat.

There are ſcarcely any metals with which gold will not unite. When boiled a ſhort time with mercury, it forms an amalgam which is gritty and rigid at the firſt, but which becomes by grinding more ſoft and tender; this is often made uſe of for gilding the ſurface of ſilver and copper, as was more particularly mentioned when treating of the latter metal.

Gold readily unites with zinc, and produces a mixed metal, whiter than might be expected from the quantity of zinc which is employed; this alloy, made with equal parts of the two metals, is remarkably ſplendid, is of a fine grain, and is not liable to tarniſh: on account of theſe properties it has been recommended in conſtructing the mirrors of teleſcopes.

All the metals, except ſilver and copper, take away the ductility of gold, but none more remarkably than tin, a grain of which added to a thouſand of gold is ſaid to deprive it entirely of ductility. Copper is commonly uſed to alloy gold, as ſilver renders it very pale. Copper rather heightens the colour of gold, but inclines it to red.

Goldſmiths denote the fineneſs of gold by the word carrat. It is ſuppoſed to be divided into twenty-four parts, called carrats; and gold, which is quite free from alloy, is ſaid to be twenty-four carrats fine; that which contains one twenty-fourth of alloy is called gold of twenty-three carrats; that which contains two twenty-fourths, of twenty-two carrats, and ſo on. In England, the ſtandard of gold coin is twenty-two carrats fine gold and two carrats of alloy, which latter is half ſilver and half copper. The French, Spaniſh, and Flemiſh gold are nearly of the ſame fineneſs.

Chap. XXXIV.

PLATINA.

Natural Hiſtory of this curious Metal.—Its Properties.—The moſt ponderous Body in Nature.—Its Hardneſs and Infuſibility.—Soluble only in Aqua Regia and oxygenated muriatic Acid.—Its Union with other Metals.—Crucibles formed of it.—Might be applied to various Uſes which no other Metal can anſwer.

IN the beginning of the year 1749, the firſt ſpecimen of this metal was brought into England from Jamaica. It was ſaid to have been originally brought from the Spaniſh Weſt Indies, and it is ſtill almoſt excluſively found in the gold mines of Spaniſh America. It is brought over in the form of ſmall ſmooth grains, irregularly figured, with round edges, and is often mixed with ferrugineous ſand and grains of quartz or cryſtal. The grains of platina are whiter than iron, but leſs ſo than ſilver, and their flat form is probably owing to the preſſure they undergo in the mills in which the gold is amalgamated.

In confirmation of this opinion, ſmall particles of gold and mercury are uſually found mixed with the grains of platina. In the ſtate in which they are brought over, they fall ſhort of the weight of gold, but by purification, which is performed by waſhing with the muriatic acid, and by expoſing them for a long time to the heat of the moſt violent furnaces, which, however, are ſaid to be inſufficient to melt

them,

them*, they exceed it. The ſpecific gravity of gold is about nineteen times that of water, whereas platina, which ſtill contains ſo much iron as to render it magnetical, is upwards of twenty-one times the weight of that fluid. It is extremely difficult to free platina from the laſt portions of iron, but ſome minute particles, which have been fuſed by the focus of a burning glaſs, and ſo far purified as not to be attracted by the magnet, appear to exceed twenty-two times the weight of water.

Platina is, perhaps, the moſt perfect of all the metals. As it ſo conſiderably exceeds even gold in weight, it is therefore to be conſidered as the moſt ponderous body in nature.

It has ſeveral properties in common with the moſt uſeful of metals, iron. In hardneſs it approaches to that metal in the ſtate of ſteel; and in infuſibility it exceeds it even in the ſtate of ſoft iron; it alſo conſiderably reſembles iron in appearance, and it is the only metal, beſides iron, which has the property of welding.

Platina reſembles gold in being ſoluble only in aqua regia, and it even requires a larger quantity of that compound acid for its ſolution than gold. The ſolution is of a deep yellow or reddiſh colour. The proportions of acids beſt adapted to the ſolution of platina are, equal parts of the nitrous and muriatic acids; but the ſolution does not then take place with rapidity. This compound is very corroſive,

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* This is the opinion of the generality of mineralogiſts; but my friend and chemical preceptor, Dr. Higgins, aſſured me, he had melted platina in his furnace.

roſive, and tinges animal ſubſtances of a blackiſh brown colour.

The vegetable alkali added to this ſolution only occaſions the precipitation of a part of the metal in the form of a ſparkling powder, which is ſoluble in a large quantity of water. A very remarkable circumſtance is, that the foſſil alkali does not produce any precipitation, unleſs added in very conſiderable quantity. Common ſal ammoniac, applied to the ſolution of platina, produces a precipitation like the fixed vegetable and volatile alkalies. It ſeparates a part of the metal in a ſparkling red powder, and a part remains diſſolved, which it cannot ſeparate; but if vegetable alkali is added after the ſal ammoniac, it precipitates the reſt of the platina; and on the contrary, ſal ammoniac, added to the ſolution containing the remainder, which the fixed alkali could not ſeparate, precipitates it, ſo that by adding both the vegetable alkali and ſal ammoniac, the whole of the platina is ſeparated. Platina, like gold, is alſo ſoluble by the oxygenated muriatic acid.

The ſubtile inflammable ſubſtances, as ſpirits of wine and aromatic oils, do not produce any ſeparation from the ſolution of platina in aqua regia, as they do from that of gold. Tin precipitates it, but the precipitation is not purple like that of gold. Moſt of the metals precipitate platina, but it does not in general fall down in the metallic ſtate. The precipitation of platina, from its ſolution by ſal ammoniac, affords a method of ſeparating this metal from the gold which is mixed with it, as the gold is not ſeparated by the addition of that ſalt; if, on the contrary, we wiſh to precipitate the gold, and leave the platina in ſolution, this may be effected by ſal martis.

The precipitates of platina may be reduced to a metallic button, by heating them with the common fluxes; but theſe cannot be rendered malleable unleſs they are completely fuſed, which can ſcarcely be effected, unleſs with the heat of the moſt powerful burning glaſſes.

A mixture of copper with platina forms a metallic body of intermediate colour and great denſity, ſo that it receives a very fine poliſh. A mixture of three or four parts of copper to one of platina poſſeſſed all the above properties in great perfection, and was not tarniſhed in the air in the ſpace of ten years. With iron it alſo produces a compound of great denſity, which is hard, ſtrong, and tough, and admits of a good poliſh. Moſt metals increaſe the fuſibility of platina ſo much, that it may be melted in ordinary furnaces.

Gold is greatly injured in colour by a mixture of platina, and becomes of the colour of bell metal by the addition of no more than one twenty-fourth part, though half that quantity produces little change.

Platina with biſmuth and tin forms alloys, which are brittle, but eaſily fuſed. Platina and lead unite very well by fuſion, but the ductility of the lead is deſtroyed, and the compound quickly tarniſhes on expoſure to air. Platina partly deſtroys the ductility of ſilver, augments its hardneſs, and impairs its colour.

Platina completely reſiſts the action of mercury, with which it ſhews no diſpoſition to unite. On this account it does not mix itſelf with the gold, which is extracted from the ſubſtances with which it is mixed by amalgamation.

From the extreme infuſibility of platina, it is excellently fitted to contain other matters, which it is intended to ſubmit to a violent heat. M. Achard ſucceeded in making crucibles of platina, by fuſing equal parts of platina, white arſenic, and vegetable alkali. This matter, when cooled, was reduced to a powder, and rammed into a mould. A ſtrong heat, quickly raiſed, and continued for ſome time, fuſed the maſs, and after diſſipating the arſenic and alkali, left the platina in the deſired form.

Platina, when thoroughly purified, by coction in the muriatic acid and precipitation from aqua regia, may be fuſed into a maſs nearly as malleable as ſoft iron. This property, united to thoſe of reſiſting acids, its great infuſibility, and welding, ſeem to render platina applicable to purpoſes which no other metal is capable of anſwering.

CHAP. XXXV.

OF INFLAMMABLE SUBSTANCES IN GENERAL.

Ignition and Combuſtion defined.—Acids formed by the Combuſtion of inflammable Subſtances.—Flame, how produced.—The Object of the preſent Inquiry limited.—What Subſtances are commonly termed inflammable.

THE difference between ignition and combuſtion conſiſts in this:—All bodies which can ſupport a certain degree of heat, without the deſtruction of their texture, emit light, and this is called ignition; but combuſtion or inflammation is a property which belongs to ſuch bodies only as are capable, when placed in proper circumſtances, of augmenting their own temperature. Simple ignition produces no permanent change in bodies, but combuſtion entirely alters the properties of ſuch as have undergone that proceſs. From being mild and nearly inſoluble in water, they become acrid, pungent, and extremely ſoluble, and are converted into acids, which differ according to the ſubſtance, by the inflammation of which they were formed. The terms combuſtible ſubſtance and acidifiable baſis are, therefore, in the French nomenclature, ſynonymous.

In the elementary part of this work it has already been remarked, that inflammation is the diſengagement of the matter of heat or caloric contained in vital air or oxygénous gas, in conſequence of the baſis of this gas becoming combined with other bodies. All bodies, therefore, which are capable of decompoſing vital air, change a quantity of latent heat into ſenſible heat, and are ſaid to be inflammable from the light and heat which ſeem to proceed from them, but which, in fact, are derived from the oxygenous gas, which is one of the component parts of the atmoſphere.

The neceſſity of the preſence of air to combuſtion is ſtrongly maintained by M. Lavoiſier, and an experiment related by him (to the latter part of which I feel ſome reluctance to give an unqualified aſſent) ſeems, indeed, to prove it to be eſſential in all caſes. He ſucceſſively placed a quantity of phoſphorus, of ſulphur, and of gunpowder, under the receiver of an air-pump, making as perfect a vacuum as the machine would admit. He then threw the focus of a lens of eight inches diameter on the different ſubſtances, which were not at all ignited, only bubbled up, and at length ſublimed. The gunpowder was decompoſed, the ſulphur of it only ſubliming, and it neither took fire nor exploded.

In ordinary language, no bodies are ſaid to be inflammable but ſuch as burn eaſily, or which, in other words, are capable of decompoſing vital air in the diluted ſtate in which it exiſts in the atmoſphere. In a more ſtrict ſenſe, however, the property of inflammability belongs to other bodies, though they poſſeſs it in a leſs eminent degree; as to zinc, which, when made extremely hot, burns with a dazzling white light, and to iron, which, when heated to a proper degree, burns in pure oxygenous gas. The oxygenation which all metals, except the perfect, undergo from the conjoined operation of heat and air, are alſo to be conſidered as caſes of ſlow combuſtion. In ſhort, all ſubſtances may be ſaid to be inflammable which are capable, in any circumſtances, of decompoſing vital air, or which have a ſtronger attraction for the baſe of that air than that baſe has for caloric or heat.

In all inſtances of inflammation a certain degree of heat is neceſſary to begin the proceſs. Different inflammable ſubſtances require different degrees of heat for this purpoſe. Phoſphorus is fully inflamed at the heat of 86 degrees of Fahrenheit, but undergoes a more gradual combuſtion at a much lower temperature. Sulphur requires much more heat than phoſphorus, and charcoal ſtill more than ſulphur. There are ſome ſubſtances in nature which are ſo combuſtible, or have ſo ſtrong an attraction for oxygen, as never to have been found uncombined with that principle; of this kind are the unknown baſes of the boracic, fluoric, and muriatic acids.

Though an acid is always formed by the combuſtion of every inflammable ſubſtance, this fact was never attended to, or at leaſt never properly apprehended, till within theſe few years. In ordinary caſes, indeed, this circumſtance was likely to paſs unobſerved; for the acid produced by the inflammation of charcoal, which is the eſſential ingredient in all kinds of fuel, is the carbonic acid gas, or fixed air, which eſcapes without leaving any traces. In the combuſtion of ſulphur alſo, the acid flies off in fumes, unleſs collected by a particular proceſs, which was deſcribed in treating of the ſulphuric or vitriolic acid. The phoſphoric acid, however, is a concrete body, and therefore cannot eaſily be overlooked. When inflammable bodies are united with oxygen they become acids, and having no longer ſufficient attraction for oxygen to decompoſe vital air, they loſe their inflammability. According to the old chemical doctrine, the heat and light afforded by inflammable ſubſtances were ſuppoſed to derive their origin from the diſengagement of phlogiſton; but, according to the doctrine of M. Lavoiſier, the vital air of the atmoſphere is the repoſitory of light and heat, from which all artificial ſupplies are derived, by means of inflammable ſubſtances.

There is one ſtriking difference among inflammable ſubſtances, which is, that ſome burn with and ſome without flame. Of the former kind are oils, ſpirits of wine, and moſt others; to the latter kind belong the different ſpecies of charcoal, and ſuch of the metals as are inflammable. The cauſe of this difference is, that ſome inflammable bodies afford an inflammable vapour, the burning of which produces flame; others are entirely fixed, and produce no ſuch vapour. The vapour, however, as it riſes is not wholly conſumed; the reaſon of which is, that the air does not find acceſs to the center of the column of vapour. Flame is a hollow cone ſurrounding a ſolid cone of vapour. In large flames, the ſurface on which the air acts is leſs in proportion to the quantity of vapour than in ſmall flames; hence the quantity of ſmoke and ſoot produced by ſmall flames is proportionably leſs than that produced by large; for ſmoke and ſoot are only that part of the vapour which is unconſumed. Upon this principle it happens that more light is afforded by candles with a ſmall wick, in proportion to the quantity of inflammable matter conſumed, than by thoſe with a large wick. The ſame end is anſwered by extending the wick in the form of a ring, and leaving room for a current of air in the middle, as is done in the patent lamps *.

In treating of inflammable ſubſtances it will be neceſſary to confine the inquiry to thoſe which poſſeſs this property in a more remarkable degree. I ſhall, therefore, firſt treat of the ſimple inflammable ſubſtances, phoſphorus, ſulphur, and coal, or the carbon of the French philoſophers. Hydrogen, or inflammable air, has already been deſcribed under the head of elaſtic or aeriform fluids. With reſpect to the compound inflammable ſubſtances, ſuch as oils, reſins, fat, &c. it will be found that they conſiſt of different proportions

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* This fact was previouſly explained in the chapter on ignition, in the ſecond book. The inflammable part of the vapour is ſo completely conſumed in Argand's lamps, that if an alembic is fixed to the top of the lamp, the matter condenſed is altogether water.

and ſtates of combination, of carbon, hydrogen, and oxygen. The inflammable matter of charcoal and coke conſiſts of carbon only; pitcoal and wood, in their crude ſtate, contain alſo ſome hydrogen, which is driven off, together with water and oil, in the proceſs of charring.

CHAP. XXXVI.

PHOSPHORUS.

Phoſphorus of Kunkel.—Light from putreſcent Subſtances.—Curious Facts.—Light from the Sea Water, &c.—Bolognian Stone.—Baldwin's Phoſphorus.—Phoſphorus of Homberg.—Pyrophori.

PHOSPHORUS* is a ſimple combuſtible ſubſtance, which was unknown to chemiſts till 1667, when it was diſcovered by Brandt, a German chemiſt, who kept the proceſs a ſecret; ſoon after Kunkel found out Brandt's method of preparation, and made it public. It has ever ſince been known by the name of Kunkel's phoſphorus. The appearance of phoſphorus is that of a tranſparent ſubſtance, of a colour inclining to yellow, like clear horn; it is ſpecifically heavier than water, is tough, and cuts like bees' wax, and like it melts with a gentle heat into a tranſparent fluid. With this heat it may be melted in water; but if the ſame degree of heat is applied in the open air, it melts, takes fire, and burns, producing a bright white flame with intenſe heat. Phoſphorus ſhould be handled with great caution, as ſhould any of it adhere to the ſkin, or get under the nails, the heat of the human body is ſufficient to inflame it. The proceſs for obtaining phoſphorus from bones was deſcribed in treating of the phoſphoric acid.

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* Derived from the Greek—" A ſubſtance affording light."

When a quantity of phoſphorus is burnt in ſmall pieces under a bell, the phoſphoric acid attaches itſelf to the internal ſurface of the bell, in the form of a downy maſs. This concrete acid has ſo ſtrong an attraction for water as to imbibe it from the atmoſphere with aſtoniſhing rapidity, till it is converted into a liquid conſiderably more denſe, and of greater ſpecific gravity than water.

From the experiments detailed in M. Lavoiſier's elementary work on chemiſtry, it appears that one pound of phoſphorus requires one pound eight ounces of oxygen gas for its combuſtion, and that two pounds eight ounces of concrete phoſphoric acid are produced.

The phoſphoric acid may be obtained by three other proceſſes beſides this. If phoſphorus is melted in hot water, and a ſtream of vital air paſſed through it, it becomes oxygenated. The ſame thing happens by plunging it in nitrous acid, from which it abſtracts the oxygen. It may be alſo acidified by ſimple expoſure to the atmoſphere, which ought not at the time to exceed the temperature of ſixty degrees, from the danger of inflammation; in this ſituation, by a gradual combuſtion, it attracts the oxygen of the atmoſphere, and becomes converted into an acid.

The cauſtic fixed alkalies diſſolve phoſphorus by the aſſiſtance of heat. During this combination a fetid gas is diſengaged, which has the ſingular property of exploding as ſoon as it comes in contact with atmoſpherical air, and ſtill more rapidly by contact with vital air.

The phoſphoric acid forms peculiar ſalts with the alkalies and ſome of the earths, and has the property of corroding glaſs. With the mineral alkali it forms a ſalt, the taſte of which is leſs unpleaſant than that of other neutral ſalts, and which is well calculated to anſwer the purpoſes for which neutral ſalts are uſed in medicine. The phoſphoric acid acts only on a ſmall number of metallic ſubſtances, but readily diſſolves, in its fluid ſtate, iron, zinc, and copper, with which it forms ſalts not cryſtallizable.

Phoſphorus ſeems to be almoſt univerſal in the animal kingdom, and is alſo found in ſome minerals, and in a very minute proportion in moſt vegetables. The bones of animals are a true phoſphat of lime, or an earthy ſalt compoſed of phoſphoric acid and calcareous earth. The urine alſo contains a conſiderable quantity of phoſphoric acid, chiefly combined with volatile alkali, but partly alſo with calcareous earth. This compound ſalt, afforded by the evaporation of urine, was formerly known by the names of eſſential ſalt of urine, or microcoſmic ſalt. Brandt, Kunkel, and Margraff, and all chemiſts, till lately, prepared their phoſphorus from that ſubſtance, but it is now almoſt entirely obtained from bones, which afford it more plentifully and with leſs trouble. Phoſphorus does not yet ſeem to have been applied to any important uſes.

From the remarkable eaſe with which phoſphorus is inflamed, ſeveral experiments may be exhibited by means of it, which appear like the effects of magic to perſons unacquainted with the nature of this ſubſtance. Thus, for example, if the outſide of a bottle is rubbed with phoſphorus, and then ſurrounded with tow, and hot water poured into it, the phoſphorus takes fire, and communicates the inflammation to the tow. If a ſtick of phoſphorus is uſed to write on a piece of paper, or on a wall, a quantity of phoſphorus is abraded, and, undergoing a ſlow combuſtion, renders the ſtrokes viſible in the dark, while in the light they can only be perceived to exhale a whitiſh vapour.

A fluid called liquid phoſphorus is prepared by digeſting ſome phoſphorus in the heat afforded by horſe dung for two days, in oil of cloves, oil of turpentine, or any ſimilar ſubſtance. After diſſolution, the oil will be ſo impregrated with it, that when the phial is opened, it will appear luminous. Any thing moiſtened with this fluid will in the dark ſeem to be on fire.

Many natural phenomena, which in the ages of ſuperſtition ſerved to aſtoniſh and affright mankind, have received a ſatisfactory ſolution from the diſcovery of the phoſphorus of Kunkel. We learn from Fabricius ab aquapendente, that three young men at Padua, having bought a lamb, and eaten part of it on Eaſter Day, 1592, ſeveral pieces of the remainder, which were kept till the day following, ſhone like ſo many candles when caſually viewed in the dark. It appears by his account, that the aſtoniſhment of the whole city was excited by this phenomenon, and a part of the fleſh was ſent to him, who was profeſſor of anatomy, to be examined by him. He obſerved, that thoſe parts which were ſoft to the touch and tranſparent in candle-light were the moſt reſplendent. A philoſopher of not leſs note, has furniſhed us with a very pompous account of a ſimilar phenomenon, which occurred at Montpelier in 1641. A poor old woman had bought a piece of fleſh in the market, intending to make uſe of it the day following; but happening not to ſleep well that night, and her pantry being adjoining to her bed, ſhe obſerved that a quantity of light proceeded from the meat, ſo as to illuminate almoſt the whole place where it hung. We may eaſily judge of the terror and aſtoniſhment of the poor woman herſelf, ſince we find that a part of the fleſh was carried, as a very extraordinary curioſity, to Henry Duke of Conde, who viewed it with the utmoſt ſurprize for ſeveral hours. The light was as if gems were ſcattered over the ſurface, and continued till the fleſh began to putrify, when it vaniſhed, which it was believed to do in the form of a croſs.

The attention of a more philoſophic age was directed to experiments to aſcertain the cauſe of this light. Mr. Boyle found, that the light of rotten wood was extinguiſhed in vacuo, and revived again by the admiſſion of air, even after a long continuance in vacuo. The extinction of the light was not ſo complete immediately on exhauſting the receiver, as ſome little time afterwards. The wood was not much affected by condenſed air; but the light of a ſhining fiſh, when put into the condenſing engine, was rendered more vivid by that means. As air is therefore neceſſary to combuſtion, theſe experiments clearly indicate, that this light is the effect of a ſlow combuſtion, or ſomething analogous to it;

and, indeed, the experiments upon the phoſphorus of Kunkel have ſince placed this matter beyond a doubt. The combuſtion, however, in theſe caſes, is ſo very ſlow, that no change of air appeared neceſſary for the maintenance of this light, for it continued for a long time, even though the wood was confined within a glaſs hermetically ſealed.

To explain the cauſe of this combuſtion it is only neceſſary to repeat what has been juſt ſtated, that there exiſts in every animal body, and in moſt vegetables, a certain quantity of phoſphorus. This principle, we have ſeen, is extremely active, and has the ſtrongeſt tendency to unite with the pure part of our common air. During that ſeparation, therefore, of the parts of bodies, which takes place in an incipient putrefaction, theſe phoſphoric particles are detached from thoſe with which they are combined, and by the action of the air, a degree of combuſtion takes place, but ſo extremely faint, that light only is produced, without the leaſt appearance of ſenſible heat.

This ſhort explanation of the cauſe will, I flatter myſelf, correſpond with moſt of the phenomena of this kind noticed by philoſophers. Mr. Boyle found that the light of rotten wood was in moſt reſpects analogous to that of putreſcent ſubſtances. The light of the former, however, differed in ſome reſpects; it was preſently quenched with water, ſpirit of wine, and a variety of other fluids; but the light of ſome ſhining veal was not entirely quenched by water, though its virtue was inſtantly deſtroyed by ſpirit of wine*. The ſame philoſopher was ſometimes diſappointed in his experiments on ſhining fiſhes; particularly he obſerved, that they failed to become luminous in cold and froſty weather, which is exactly agreeable to the nature of phoſphorus, ſince its combuſtion is exactly in proportion to the heat which is applied to it. He remarks alſo in another place, that the light of ſhining wood was completely extinguiſhed by extreme cold.

Some bodies have a much greater tendency to produce this light than others. A foreign philoſopher remarked, that on opening a ſea polypus it was ſo luminous as to ſtartle moſt of the perſons who ſaw it; the nails and the fingers of thoſe who touched it became luminous alſo. The light of the glow worm, and other luminous inſects, muſt depend upon ſome ſlimy or fluid matter which they emit, and which has this tendency to ſhine. There is a remarkable ſhell-fiſh, called *pholes*, which forms for itſelf holes in different kinds of ſtone. This fiſh illuminates the mouth of the perſon who eats it; and it is remarked, that contrary to the nature of other fiſh, which give light when they tend to putreſcence, this is more luminous the freſher it is, and when dried its light will revive on being moiſtened either with ſalt water or freſh; brandy, however, immediately extinguiſhes it †.

The luminous appearance of the ſea in the night time cannot have eſcaped the obſervation of any perſon in the leaſt converſant with that element. The light occaſioned by the daſhing of oars, or by the motion of the waves by night, is extremely beautiful. Father Bourzes, in his voyage to the Indies in 1704, remarked particularly the luminous appearance of the ſea. The light was ſometimes ſo great, that he could eaſily read the title of a book by it, though nine or ten feet from the ſurface of the water. Sometimes he could eaſily diſtinguiſh, in the wake of the ſhip, the particles which were not luminous from thoſe that were. The luminous particles alſo appeared of different forms; ſome appeared like points of light, others like ſtars; ſome of them reſembled globes of a line or two diameter, and ſome appeared as large even as a man's head; they aſſumed ſquare and triangular as well as globular forms, and not only the wake of the ſhip, but fiſhes in ſwimming, produced theſe luminous appearances. All theſe phenomena he attributes, and rightly, to the fat or putreſcent ſtate of the water, and obſerved, that when the wake of the ſhip was brighteſt, the water was moſt clammy and glutinous. In ſome parts of the ſea, he ſaw a ſubſtance like yellow and red duſt, and the ſailors told him it was the ſpawn of whales which produced all theſe appearances*. Later experiments have proved, that the luminous appearance of the ſea entirely proceeds from the putreſcent parts of marine animals†.

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* *Prieſt. Op.* 565.

† Ibid. 567.

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* *Prieſt. Op.* 572. † Ibid. 576.

Human bodies, as well as thoſe of other animals, emit light juſt when they begin to putrify; and the walls and roofs of places in which dead bodies have often been expoſed have been obſerved to have a ſlimy matter depoſited on them, which was luminous in the dark. The lights which are ſometimes ſeen in burial grounds undoubtedly proceed from this cauſe alone*. Similar appearances have been obſerved about the beds of ſick perſons, probably in putrid diſeaſes: one of theſe was obſerved about the body and the bed of a ſick woman at Milan, which fled from the hand that approached it, but was at length diſperſed by a ſtream of air. It is well known that the ſweat often contains a conſiderable quantity of phoſphoric matter †.

Certain ſtony matters are called phoſphoric, but do not in fact contain a particle of that ſubſtance. The moſt remarkable ſtone of this kind has been already noticed, I mean the *Bolognian ſtone*, ſo called from the place where it is uſually found. Margraff ſays, that the Bolognian ſtone is ſoft, friable, heavy, cryſtallized, and incapable of effervefcing with acids, till it has been calcined in contact with fuel, and with a free acceſs of air. Theſe qualities have induced him to claſs it among the heavy fuſible ſpars, all of which are capable of being rendered phoſphoreſcent. After analyzing theſe ſubſtances, he concludes, that they all contain vitriolic acid combined with calcareous earth, and that they are of courſe ſelenites. In order to make theſe ſtones phoſphoreſcent, they muſt be heated red hot, and afterwards reduced to powder. This is to be made into a paſte with gummy matter, and to be cut into cakes as thin as a knife. After theſe cakes have been heated in contact with charcoal, they are fit for uſe. What is called the phoſphorus of Baldwin is a combination of chalk with nitrous acid; and the phoſphorus of Homberg is a combination of quick lime with muriatic acid. All theſe ſubſtances have the property of ſhining in the dark for ſome minutes, after having been expoſed to the light of the ſun, or, according to Margraff, after having been ſimply heated. Moſt ſubſtances, after having been held in a bright light, emit ſome faint light on being ſuddenly removed into a very dark place, but the light afforded by the ſubſtances above deſcribed is ſo remarkable as to have attracted particular attention.

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* *Prieſt. Op.* 576.

† Ibid. 587.

Bolognian ſtone can be illuminated by the light of a candle, but not by the light of the moon, or of another phoſphorus. When one part of it is illuminated, it is not communicated to another. Two ſeconds will give it all the light it is capable of receiving, but one ſecond will imperfectly illuminate it. Some ſpecimens will continue viſible for thirty minutes; but in general the light is not vivid for more than four minutes.

Father Beccaria, having incloſed ſome pieces of extraordinary good ſolar phoſphorus in tubes, into which the light was admitted through glaſs, aſſerts, that the phoſphorus was of that colour only which it imbibed. All theſe phoſphori will loſe their virtue by being long expoſed to open day. Some of them will preſerve their beauty a long time though plunged in water, which in the end, however, deſtroys them; ſome of them will ſhine with peculiar ſplendor, while diſſolving in warm water, which is partly to be attributed to the heat they imbibe in this proceſs.

The ſubſtances known by the name of pyrophori, which ſpontaneouſly take fire when expoſed to the air, are variouſly prepared. A pyrophorus may be very eaſily made, by mixing alum or any vitriolic ſalt with charcoal, or any matter containing charcoal, and keeping them in a red heat for an hour, the air being excluded; this operation may be performed in the bowl of a tobacco pipe. The pyrophori, when made, muſt be very carefully kept from the air; for if the veſſel in which they are contained ſhould be accidentally opened or broken, there is danger of their ſetting fire to any thing with which they come in contact.

The calcareous, or ſolar phoſphori, and the pyrophori, have two ſtriking circumſtances in common, which are, that they are both prepared by the application of heat, and both loſe their properties by expoſure to air; that their properties, therefore, proceed from the ſame cauſe, is extremely probable, and this cauſe may probably be the attraction of oxygen from the atmoſphere. It has been imagined, that the calcareous phoſphori loſe their property by expoſure to light; but this is a miſtake, for its properties remain uninjured by expoſure to light in cloſed veſſels.

It muſt be confeſſed, however, that the nature both of the calcareous phoſphori, and of the pyrophori, has never been fully explained. It is only neceſſary in this place to caution the reader againſt confounding them with phoſphorus, the proper ſubject of this chapter, from which they are eſſentially different.

Dr. Prieſtley put a quantity of pyrophorus into one of the ſmall jars uſed for making experiments upon air in quickſilver, then filling up the veſſel with that fluid, he inverted it in a baſon of the ſame, and threw in dephlogiſticated air at different times: it always occaſioned a ſudden and violent accenſion, like the flaſhing of gunpowder, and the air was greatly diminiſhed.

CHAP. XXXVII.

SULPHUR.

General Properties of Sulphur.—Natural Hiſtory of Sulphur.—Union with Earths.—With Alkalies.—Liver of Sulphur.—Artificial ſulphureous Waters.—Uſes of Sulphur.

SULPHUR is another ſimple inflammable ſubſtance, which agrees in ſome properties with phoſphorus. Like that it melts with a gentle heat, and is capable of a gradual as well as of a rapid combuſtion, in proportion to the degree of heat applied to it.

In treating of other bodies, particularly the metallic, ſeveral have been mentioned with which ſulphur is found united in the bowels of the earth: few ſubſtances are indeed more abundant in nature than ſulphur; it alſo enters into the compoſition of animal matters, and, in a very ſmall proportion, into that of vegetables.

The ſulphur of commerce is extracted, by diſtillation, from the ſubſtance which has been ſo often mentioned under the name of pyrites, in which ſtate it is combined with iron, and is ſo hard as to ſtrike fire with ſteel. Pyrites in colour and appearance reſemble braſs; ſome pieces are cubical, but in general this mineral has no determinate form. The ſulphur obtained by the firſt diſtillation is ſeldom pure, from the ſteams of other volatile ſubſtances which riſe and are condenſed with it. It is purified by being melted in a ladle, and kept in that ſtate till the impurities ſettle at the bottom. If it is an object to obtain ſulphur of the greateſt purity, this muſt be effected by ſublimation; and in this ſtate it is commonly ſold under the name of flowers of brimſtone. Even theſe, however, are ſometimes rendered impure by the ſulphur taking fire, which produces a mixture of vitriolic acid. This is effectually removed by boiling the flowers in water, which diſſolves the acid, and leaves the ſulphur in a pure and mild ſtate.

Sulphur is ſometimes found, more or leſs pure, in the neighbourhood of volcanos, in which caſe it ſeems to have been ſeparated, by ſubterraneous heat, from ſome ſubſtance with which it was previouſly combined.

The method of burning ſulphur for the preparation of the vitriolic acid has already been deſcribed when treating of that acid.

Sulphur has no action on ſiliceous earths, but very readily unites with the calcareous. It is alſo capable of combination with magneſia, ponderous earth, and volatile alkali. It unites, however, with much more violence with the fixed alkalies. All theſe combinations are of a liver colour, and are therefore called livers of ſulphur. By M. Lavoiſier they are much more properly denominated ſulphurets of theſe ſeveral ſubſtances, as ſulphuret of lime, ſulphuret of magneſia, &c. Theſe ſubſtances are ſoluble in water, and have conſiderable action on a variety of other bodies. The combinations of ſulphur with earths and alkalies may be all decompoſed by means of acids, and the earthy ſulphurets by means of the fixed alkalies. Theſe ſubſtances, when diſſolved in water, diſengage a peculiar gas called hepatic gas. This gas is preciſely the ſame, from whatever kind of ſulphuret it proceeds; but none of them afford it unleſs mixed with water. This gas, therefore, proceeds from a decompoſition of water, and is found to conſiſt of ſulphur diſſolved in inflammable air. When this gas comes in contact with vital air it is decompoſed, the vital air and hydrogen uniting to form water, while the ſulphur is precipitated in ſmall flakes. This gas is capable of ſolution in water, and by theſe means natural ſulphureous waters may be imitated.

The chief uſes to which ſulphur is applied are, the making of gunpowder and vitriolic acid. It is alſo uſed in bleaching, and is an article of ſome importance in the materia medica.

CHAP. XXXVIII.

THE CARBONACEOUS PRINCIPLE.

Nature of the Carbonaceous Principle.—In what Subſtances principally found.—Charcoal.—Lamp-black.—Strong Attraction of the Carbonaceous Principle for Oxygen.—Its Uſe in the Reduction of Metals.—Plumbago, or Black Lead.—Its various Uſes in the Arts.

THE word carbon is adopted from the nomenclature of the French chemiſts, to expreſs an inflammable matter which conſtitutes the chief part of the weight of charcoal, pitcoal, &c. and which, with different proportions of hydrogen, or the baſe of inflammable gas, forms the different kinds of oil.

By the combuſtion of carbon a peculiar acid is formed, which is ſoluble in water, unites with alkaline baſes, and poſſeſſes all the properties of acids in general, though in a weak degree. This acid has already been treated of under the name of carbonic acid gas, or fixed air.

Carbon exiſts in great quantities in foſſils, as the greater number of calcareous ſtones and earths are found united with it; it is alſo one of the conſtituent parts of the atmoſphere, in both which ſtates it is combined with oxygen. It is found united with earthy matter and oil in the extenſive ſtrata of pit-coal, and with iron in the matter which is called plumbago, or black lead. Carbon alſo exiſts in all vegetable and animal ſubſtances, and conſtitutes a conſiderable part of their weight, particularly of thoſe vegetable matters which are the moſt firm. The ſtate of greateſt purity to which carbon can be reduced is, by burning wood in ſuch a manner as to reduce it to charcoal, which, when well made, contains carbon united with only a very ſmall proportion of ſuch matter contained in vegetable ſubſtances as cannot be driven off with heat, ſuch as earthy and ſaline matter, with a very minute portion of iron. In order to convert wood into charcoal, the only circumſtances neceſſary are the application of heat while the air is excluded. The only elementary ſubſtances which ſeem to be univerſal in the vegetable kingdom are, carbon, hydrogen, and oxygen. The former of theſe ſubſtances has very little attraction for caloric, or the matter of heat, and therefore cannot be driven off in vapour, at leaſt by the heat of ordinary fires; the two latter, however, have a ſtrong attraction for that principle, and therefore eaſily aſſume a gaſſeous ſtate. In the ordinary temperature of the atmoſphere the carbon, hydrogen, and oxygen, which conſtitute the woody fibre, ſeem to exiſt in a ſtate of triple combination; but this is not the caſe when the temperature is altered. According to M. Lavoiſier, if a heat, not exceeding that of boiling water, is applied, one part of the hydrogen combines with oxygen, and forms water, the reſt of the hydrogen combines with a part of the carbon, and forms volatile oil, while the remainder of the carbon remains fixed at the bottom of the veſſel. If a red heat, however, is applied, no water comes over, carbon having a ſtronger attraction at that temperature for oxygen than hydrogen has, and therefore carbonic acid is produced; and the hydrogen being left free from other combinations, unites with caloric, and comes over in the form of hydrogen gas. In this high temperature no oil is produced.

The ſolidity of charcoal depends on that of the wood from which it is procured, and the care, with which the proceſs is conducted. In general it preſerves the form of the vegetable, unleſs that was very ſucculent. Pure oils, from decompoſition by heat, afford a coal in very fine particles, called lamp-black.

In whatever manner the volatile matters can be diſpelled from vegetable or animal ſubſtances without the admiſſion of vital air, which would conſume the carbon, charcoal is produced, which contains no ingredient capable of inflammation except carbon, and therefore, with reſpect to that proceſs, may be conſidered as carbon itſelf.

Charcoal, expoſed to the greateſt heat without the preſence of vital air, remains unconſumed and unchanged. This fact has been denied by the advocates for the phlogiſtic hypotheſis, who maintain that the pureſt charcoal, treated in this way, affords a quantity of inflammable gas. It is now, however, I believe, commonly admitted, that if the charcoal is firſt accurately dried, no inflammable gas is produced, and therefore that which has been obſerved by other chemiſts is to be attributed to the preſence of a ſmall quantity of water, which, in a high temperature, is decompoſed by charcoal. Dr. Prieſtley has obſerved, that charcoal has a ſtrong diſpoſition to attract humidity from the atmoſphere. He found that charcoal prepared in the evening, and kept till the morning, became ſenſibly moiſt, and unfit for nice experiments. This remarkable attraction for water is, perhaps, to be attributed to the alkaline ſalts uſually contained in charcoal.

From the very ſtrong attraction which the carbonaceous principle has for oxygen, there is no ſubſtance that can be applied to ſeparate it from that matter. Carbon, on the contrary, is capable of decompoſing all the acids except the boracic, the fluoric, and the muriatic, the unknown baſes of which have a ſtronger attraction for oxygen than itſelf.

Charcoal readily decompoſes the phoſphoric and ſulphuric acids, the baſes of which burn at a lower temperature; and this fact evinces, that the degree of heat at which the combuſtion of a body begins does not accurately mark its degree of attraction for oxygen.

From the ſtrong affinity of the carbonaceous principle for oxygen, charcoal is the moſt powerful ſubſtance which can be uſed in the reduction of metals. Charcoal has alſo another advantage over other inflammable ſubſtances in theſe operations, which is, that it bears a great degree of heat without volatilization.

According to the experiments of Lavoiſier, in the combuſtion of one pound of charcoal, two pounds, nine ounces, one drachm, ten grains of oxygen gas are abſorbed, and three pounds nine ounces one drachm ten grains of carbonic acid gas are formed.

The carbonaceous principle, or carbon, is one of the moſt important ſubſtances in nature. It is one of the neceſſary conſtituent parts of animal ſubſtances, and enters into the compoſition of all alimentary matters, flour, ſugar, mucilage, oil, &c. It is alſo the chief ingredient in all kinds of fuel.

Plumbago, or black lead, is found to conſiſt of carbon combined with about one-tenth of its weight of iron. It appears to be ſcarcely inflammable, but may, however, be almoſt entirely conſumed with the production of carbonic acid gas, by keeping it heated to a great degree, and agitated ſo as to expoſe it thoroughly to the air. It may be alſo deflagrated with a large proportion of nitre in a red heat. It is found in a ſeparate ſtate in a variety of places; but the ſpecies beſt adapted for making pencils comes chiefly from Burrowdale, in Cumberland. For this purpoſe it is cut into thin plates, the edge of which, being fitted into a groove in a ſemi-cylinder of wood, is then ſawed off, ſo as to leave the cavity entirely filled. The black lead is retained in its place by the other half of the cylinder, which is glued on. The makers of ſmall ſhot poliſh and blacken its ſurface by agitating or rolling it in a caſk with powder of plumbago. This mineral is likewiſe uſed in the manufacture of razor-ſtraps.

CHAP. XXXIX.

PITCOAL.

Different Species of Coal.—Newcaſtle Coal.—Culm.—Slate Coal.—Cannel Coal.—Kilkenny Coal.—Bovey Coal.—Peat.—Coke.—Coal Tar.—Natural Hiſtory of Coal.—Obſervations relative to the Deluge.

PIT COAL is a ſubſtance of which there are many varieties, the cauſes of which have not been aſcertained, as all the kinds afford very nearly the ſame reſults by chemical analyſis. The moſt remarkable varieties are,

1. NEWCASTLE coal is of a black colour and ſhining appearance, where it has been lately broken. This ſubſtance undergoes an imperfect fuſion when heated, ſo as to cohere or cake. It burns with a lively flame, and is nearly conſumed in the fire. It does not break equally in all directions, and is compoſed of laminæ.

2. CULM coal. This contains a large proportion of argillaceous earth, ſo that after being burned its bulk is ſcarcely diminiſhed. It burns with a lively flame, but its appearance is more dull and earthy than that of the former. This kind of coal is found in Sweden, and in ſome parts of England.

3. SLATE COAL. This has very much the appearance of ſome of the common kinds of ſlate, but it burns very eaſily, with a copious and bright flame. It conſiſts chiefly of argillaceous earth, and ſeems to

have only been penetrated with bituminous or coaly matter.

4. Cannel coal is of a dull black colour, breaks eaſily in any direction, and in its fracture preſents a ſmooth conchoidal ſurface, if broken tranſverſely. It is nearly conſumed in the fire, burns with a lively flame, but if ſuddenly heated flies in pieces with conſiderable violence. This inconvenience is ſaid to be removed by previouſly immerſing it in water for ſome hours*. Cannel coal does not ſoil the fingers, and admits of being turned into ſnuff boxes, inkſtands, trinkets, &c.

The word lithonthrax, uſed by ſome mineralogiſts, properly denotes ſtone coal, and ſeems moſt applicable to cannel coal, as this, from its dull and uniform fracture, has moſt reſemblance to a ſtony ſubſtance.

5. Kilkenny coal. This is perhaps the moſt free from earthy matter of all the different ſpecies of coal; the earth contained in it not exceeding the twentieth part of its weight. This coal burns with leſs flame and ſmoke †, and more ſlowly and intenſely than the cannel coal.

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[*] It is cuſtomary in Lancaſhire to ſprinkle ſalt upon cannel coal, to prevent its flying; but I cannot ſpeak deciſively as to its effects, having never ſeen the experiment accurately made. Poſſibly the water contained in the ſalt may have ſome influence in preventing the cracking of the coal.

[†] Kilkenny, the town in Ireland where this coal is produced, is pleaſantly ſituated; it is watered by a clear and beautiful river, and produces alſo a black marble variegated with white ſpots. The place has therefore been proverbially characterized—“ Fire without ſmoke, air without fog, water without mud, and the ſtreets paved with marble.”

6. Sulphureous coal. All thoſe kinds of coal are called by this name, which are mixed with particles of a yellow and metallic appearance, and which are in fact a ſpecies of pyrites. In conſequence of this admixture they emit, when burned, a ſulphureous ſmell, and fall to pieces when expoſed to the action of air and moiſture.

7. Bovey coal, xylanthrax, is of a brown or browniſh black colour, and of a yellow laminar texture. The laminæ are frequently flexible when freſh dug, though they generally harden on expoſure to air. It ſeems to conſiſt of wood penetrated by petrol or bitumen, and frequently contains pyrites, alum, and vitriol.

8. Peat or turf, geanthrax. It may admit of doubt how far it is proper to conſider peat among the ſpecies of coal; but as ſome philoſophers of great authority have attributed every kind of coal to a vegetable origin, and as ſome kinds are deciſively ſo, the reaſon of this arrangement will be obvious. What is properly called peat is formed by the growth of a particular vegetable matter, peat moſs, which increaſes to ſuch a degree in mooriſh grounds as to form ſtrata of many feet in thickneſs. When peat is freſh dug from below the ſurface, it is of a viſcid conſiſtence, but hardens by expoſure to the air. It is often mixed with pyrites and ſtony matters, which are ſeparated from it while ſoft, in which ſtate it is formed into oblong maſſes for fuel. When diſtilled, it affords water, oil, and volatile alkali, which are preciſely the products afforded by the diſtillation of pit-

coal. A kind of peat is found near Newbury, in Berkſhire, which contains but little earth, and conſiſts of wood, branches, twigs, roots, with leaves, graſs, ſtraw, and weeds. What is dug on moors, under the name of turf, frequently contains a mixture of peat.

Coal, when heated and inflamed to ſuch a degree as to expel the more volatile parts, forms a kind of mineral charcoal, called COKE, which is highly uſeful in the property of affording a ſtrong, clear, and laſting fire, without forming a coheſive maſs, which would prove very prejudicial in the ſmelting of metals. It is alſo uſed in drying thoſe ſubſtances which would be injured by the thick ſmoke of common coal.

Lord Dundonald was the firſt perſon who improved this proceſs, by collecting the tar and volatile alkali, which are driven off from the coal, while it is converted into coke. His method has been adopted with much advantage in ſeveral parts of Britain. The coal is put into ovens, which are heated by fires lighted beneath, and the liquid matter is forced through an iron pipe inſerted into the top of the oven, and which communicates with proper condenſing veſſels. By this proceſs a corroſive watery liquor and two ſorts of oil are obtained. Six barrels of the mixed oily matter produce about five barrels of oil of a thicker conſiſtence; of the oil thus thickened, one part is lighter than the other, which is drawn off, and is not at preſent applied to any uſe*. The thicker part is uſed as an inferior kind of tar.

Coal, like moſt other conſiderable maſſes of matter found near the ſurface of the earth, is diſpoſed in beds or ſtrata, which are ſometimes parallel with the horizon, but generally form different angles with reſpect to it; the ſame ſtratum uniformly preſerves the ſame direction. The ſtrata of coal are diſpoſed between ſtrata of other matters. The following ſtrata are uſually found in thoſe diſtricts of country, both in England and Scotland, where coal abounds: whinſtone, freeſtone, ſandſtone or freeſtone of a coarſer texture, metalſtone, which is a hard argillaceous ſubſtance, containing balls of iron ore and ſhiver, which is the moſt common of them all, and is an indurated bole, uſually of a blackiſh colour.

Theſe ſtrata do not bear on each other in the ſame order in different collieries, nor are they of any uniform thickneſs. The ſtrata of coal themſelves are divided by other partings, called *backs* and *cutters*, into innumerable cubic, priſmatic, and rhomboidal figures.

In all places where the ſtrata lie regularly, they are divided and ſubdivided in the manner above mentioned, and ſometimes extend uninterruptedly through a conſiderable diſtrict. This regularity, however, is frequently broken by gaps filled by other matter, which has evidently fallen in, in conſequence of the ſtrata having been ſeparated from each other by ſome violent convulſion. The largeſt gaps are called dykes, and deſcend from the ſurface of the earth, ſometimes perpendicularly, ſometimes obliquely, to the greateſt depths ever tried. On each ſide of theſe gaps the ſtrata correſpond, but they are often ſunk ſeveral feet or fathoms lower on one ſide than the other, and this is called a dip.

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* See Biſhop Watſon's Eſſays.

With reſpect to the origin of pitcoal, it is the opinion of Dr. Black, Biſhop Watſon, and other philoſophers of high reputation, that the ſtrata of coal were formerly large collections of vegetable matter at the ſurface of the earth. In diſtant ages, Britain was probably almoſt entirely covered with immenſe foreſts and collections of peat moſs, which (according to the opinion of theſe naturaliſts) being covered with quantities of ſand or earth brought by floods, or by more gradual cauſes, as the falling of the ſubſtance of the neighbouring hills, has been preſſed and conſolidated, in courſe of time, into the ſubſtance called pit coal. The ſurface of the earth has alſo been probably rendered unequal in a variety of places by the action of earthquakes; this would give riſe to the formation of lakes in thoſe places which were depreſſed. In this manner, a quantity of vegetable matter would become covered by depoſition from water. Volcanic eruptions muſt often alſo have overwhelmed large collections of vegetable matters. We even find vegetable matter in an intermediate ſtate between organized vegetable ſubſtances and coal; for peat has ſtill ſome ſmall remains of organic texture, but ſeems chiefly to conſiſt of oily and inflammable matter, which only requires time and the preſſure of ſupeincumbent ſtrata to convert it into the firm and compact texture of coal. In ſome places, the remains of foreſts have been obſerved converted into an imperfect pit coal, in which the trunks, branches, bark, and roots of trees, are diſcernible. In the neighbourhood of coal pits, impreſſions of vegetable matters, and particularly of fern, are uſually obſervable. Now it is remarkable, that both peat moſs and fern are produced on wild and uncultivated lands, and this renders it ſtill more probable, that coal in general owes its origin to peat moſs. Coal is found in thin and broad ſtrata, ſuch as might be expected on the ſuppoſition of its being derived from the decay of peat moſs, or collections of other vegetables on the ſurface of the earth. Coal is often covered with matter which cannot be ſuppoſed to have been created in its preſent ſtate, as ſandſtone, the particles of which are evidently owing to the motion and friction occaſioned by water. It has been already mentioned, that the products afforded by the diſtillation of peat moſs and pit coal are preciſely the ſame. We know of no ſubſtance purely and unqueſtionably mineral, which affords products at all ſimilar, and it therefore on the whole ſeems probable, that the ſtrata of coal found in different countries, however extenſive, owe their origin to vegetable matter. The bituminous matters ſeem alſo to be exudations from vegetable matters buried in the earth.

In confirmation of the ſame opinion, I add the following extract from the late ingenious Mr. Whitehurſt's Inquiry into the original State of the Earth. 'All the ſtrata incumbent on coal, whether argillaceous ſtone or clay, contain figured ſtones, repreſenting a vaſt variety of vegetables, or the impreſſions of them, as reeds of various kinds, ſtriated and jointed at different diſtances, the euphorbia of the Eaſt Indies, the American ferns, corn, graſs, and many other ſpecies of the vegetable kingdom. They are incloſed in the ſolid ſubſtance of the ſtone, &c. Theſe vegetable forms, and the ſtrata containing them, are the certain indication of coal, not only in Derbyſhire, but in every part of the kingdom which I have viſited; and I am informed, that the ſame phenomenon holds equally true in every other part of the world yet explored.' In general, the ſtone which holds foſſil plants is either very hard and cloſe, or bituminous, ſo as to afford no acceſs to water.

The great difficulty in this hypotheſis reſults from the immenſe quantities of theſe matters which are found in the earth, and this difficulty can only be removed by referring to a fact, which is ſupported by the traditions of every nation upon earth, the univerſal deluge.

Among many other curious obſervations, relating to the deluge and its remains, made by Dr. Scheuchzer and his brother, the Doctor informs us of the trunk of a tree, nine Paris feet in length, with ſome part of its branches ſtill left upon it, which is lodged upon the ſummit of mount Stella, the chief of all the Alps of Switzerland, which, according to the barometer, is more than two Engliſh ſtatute miles perpendicular in height, and four thouſand feet higher than any trees or vegetables are obſerved to grow; he concludes, therefore, that it was left there by the ſubſidence of the waters of the deluge. Another modern writer alſo very properly remarks, 'When we find on any ſtones an exact reſemblance of a plant, a leaf, or ſome fruit, that we are acquainted with, if theſe leaves are bent or folded, if they croſs each other, or lie one upon another, they are certain indications that the plant or fruit ſo repreſented is an impreſſion made by a natural body*.' Specimens of this deſcription are frequently found.

Not only vegetables, however, but parts of animals alſo, are met with, deeply plunged in the ſtrata of the earth, for the preſence of which, in ſuch ſituations, we cannot account, except by ſuppoſing, that they were depoſited during the deluge, when not only the windows of heaven were opened, but the fountains of the great deep were broken up; expreſſions which denote, in the ſtrong ſtyle of oriental imagery, the extenſiveneſs of that vaſt diſturbance or convulſion which happened to this globe. A foſſil ſkeleton of an alligator, twelve or fourteen feet in length, was diſcovered in the cliff of an alum rock, near Whitby, in Yorkſhire. In a gravel pit of Suffolk, abounding with foſſil ſhells, the entire ſkeleton of a whale was diſcovered, the bones of which, when they became friable by expoſure to the air, were employed by a farmer for the manuring of his land. Fragments of an elephant's tooth were dug from a gravel pit at the end of Gray's Inn Lane, at the depth of twelve feet. From theſe and other facts it ſeems probable at leaſt, that this part of the world, before the flood, contained animals which now are very rarely found, or are totally incapable of exiſting in ſuch a climate. This conſideration will lead us to conclude, that the deluge not only deſtroyed the greater part of the animals then exiſting, but produced a conſiderable alteration in the conſtitution of the globe, and a permanent revolution in ſome of the laws of nature, of which the change that took place in the length of human life is one ſtriking inſtance. The earth, and almoſt every part of it, is ſtored with the remains of trees, plants, and fruits; of fiſh, teſtaceous, cruſtaceous, and ſquamous, and of other occaſional inhabitants of the waters. The ſpoils of land animals are alſo met with, but in much ſmaller quantities, which it is not difficult to account for, when we conſider, that the waters of the ſea occupy more than twice as much of the globe as the land, and that the waters are much more copiouſly ſupplied with animals of conſiderable magnitude, than the land. Add to this, that the claſſes of corallines, lithophuta, and many of the teſtaceous kinds, are of a ſubſtance as hard as ſtone, and of a much more durable texture; whence it is not to be accounted a matter of ſurprize that they abound ſo much in the earth in the form of petrifactions. We are to recollect alſo, that the cataſtrophe of a deluge would ſoon corrupt, deſtroy, and diſperſe the parts of ſuch living creatures as die in the waters; while the natives of the ſea would ſtruggle with the difficulties of an inundation, and be at laſt depoſited, perhaps alive, in the earth, when the ſettlement of the ſtrata took place, and the waters retreated, as it is evident that many of them actually were, from the poſtures and circumſtances in which they have been diſcovered*.

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* Le Pluche Spect. de la Nature, Dial. 25.

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* See Jones's Phyſiological Diſquiſitions.

CHAP. XL.

NAPHTA, PETROLEUM, BARBADOES TAR, &c.

Nature and Properties of Naphta.—Burning Fountains.—Petroleum.—Mineral Pitch, or Barbadoes Tar.—Lake Aſphaltes.—Aſphaltum; how collected.—Elaſtic Bitumen.—Component Principles of theſe Subſtances.

ALL theſe ſubſtances are of the bituminous kind, and are, indeed, all of the ſame nature, but differ in conſiſtence. Naphta is an oily fluid, which, in its greateſt degree of purity, is nearly colourleſs, is extremely volatile and ſubtile, and ſo light as to float even on ſpirits of wine. It has a ſtrong oppreſſive ſmell, and evaporates ſpontaneouſly. Like other oils, it burns with ſmoke. It is ſaid to be gathered at the ſurface of certain wells in Perſia, and is rarely found in Europe.

The vapour of naphta, which iſſues through the crevices of the earth, is generally ſuppoſed to be the cauſe of the flame which is ſometimes obſerved on waters, fountains, &c. At Chittagon, in the Eaſt Indies, there is a fountain which burſts into flame of its own accord, whenever it has been extinguiſhed by accident; this fountain has its deity and its prieſts; and ſome Europeans, ſuſpecting the whole to be a pious fraud, pulled down the wall, &c. but found that the vapour actually kindled ſpontaneouſly when put out. It is poſſible, however,

ever, that this flame may be fed by inflammable air inſtead of naphta.

Petroleum, which is of a thicker conſiſtence, and more weighty than naphta, is much more common. It is of a yellow or brown colour, and is found in Switzerland, Sicily, Italy, and France. It iſſues from the crevices of rocks, or is found floating on the ſurface of ſprings. The different kinds of petrolea, on diſtillation, yield naphta, while a coaly reſiduum remains in the retort.

Barbadoes tar is of a thicker conſiſtence than petroleum, and is alſo called mineral pitch; it was formerly found near Babylon, and conſtituted, according to Vitruvius, when mixed with lime, the cement which was uſed in building the walls of that city. It is at preſent found in ſeveral parts of Europe and in America, where it drops, or diſtils, gradually from rocks.

Aſphaltum is a ſubſtance much reſembling Barbadoes tar; it is alſo called Jews pitch, and is thrown up in a liquid form from the bottom of the lake where Sodom and Gomorrah anciently ſtood. From the production of this ſubſtance this was called the Lake Aſphaltes, from a Greek word denoting bitumen. The bitumen floating on the ſurface of the water is hardened by the heat of the ſun, and is in that ſtate collected by the Arabs on the ſhore, where it is thrown. The eaſtern aſphaltum is ſeldom brought to Europe, but is uſed by the inhabitants as pitch.

All theſe thicker bitumens may be rendered thinner by diſtillation, and may be converted into

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an oily fluid, the tenuity of which is increaſed by the repetition of the proceſs; at every diſtillation a quantity of charcoal, earthy matter, and carbonic acid gas, being ſeparated from them.

In *Obſervations ſur la Phyſique*, for January, 1788, vol. xxxii. M. de la Metherie makes mention of a mineral elaſtic bitumen analogous to the caoutchouc, or elaſtic gum, and which is found in Derbyſhire.

The production of all theſe bitumens is attributed to the action of ſubterraneous fire on ſtrata of pitcoal, by which the oily parts are ſeparated and ſublimed in the ſame manner as by artificial heat.

Biſhop Watſon mentions a curious experiment, which illuſtrates the relation of theſe four bitumens to each other. The moſt tranſparent oil of turpentine, reſembling naphta, may be changed into an oil reſembling petroleum, by mixing it with a ſmall portion of vitriolic acid; with a larger proportion of the acid the mixture becomes black and tenacious like Barbadoes tar, and the proportions of the ingredients may be ſo adjuſted, that the mixture will even acquire a ſolid conſiſtence like aſphaltum.

CHAP. XLI.

JET, AMBER, AMBERGRIS, AND MINERAL TALLOW.

General Properties of Jet.—Its Nature and Origin.—Amber.—Acid of Amber.—Natural Hiſtory of Amber.—Different Opinions of its Origin.—Ambergris.—Its Natural Hiſtory.—Mineral Tallow.

JET is a very compact bitumen, harder than aſphaltum, always black, and ſuſceptible of a good poliſh. It is ſo light as to ſwim on water; becomes electrical when rubbed, and is called black amber. When burned it emits a bituminous ſmell. Jet ſeems nearly allied to coal, and particularly to that ſpecies which is called cannel coal; it is diſtinguiſhed chiefly by its ſtructure, being compoſed of fibres parallel to each other like thoſe of wood. It ſeems in fact to be wood, which has been long buried in the earth, and penetrated by mineral ſteam, ſo as to aſſume the appearance and ſolidity of coal.

Amber is the ſubſtance known to the ancients under the name of electrum and ſuccinum. In this ſubſtance the property, which certain bodies have, of attracting light ſubſtances, when rubbed, was firſt obſerved, and was therefore called electricity. The moſt valuable amber is perfectly tranſparent, of a pale yellow, and is much more eſteemed when it happens to contain any extraneous ſubſtance, ſuch as leaves, inſects, &c. When broken it preſents a poliſhed ſurface at the place of the fracture. Amber does not readily diſſolve in any fluid we are yet acquainted with. Spirit of wine has ſome ſmall effect upon it, and from this combination a tincture is produced, but the quantity it diſſolves is very ſmall. When applied to the flame of a candle it readily takes fire, and burns with a bright white flame and thick ſmoke, and leaves a conſiderable quantity of charcoal. Amber expoſed to heat, without the action of flame, ſoftens and ſwells very conſiderably. Diſtilled in a retort by a heat gradually raiſed, it affords a watery fluid of a red colour, manifeſtly acid; this acid ſpirit retains the ſtrong ſmell of amber; an acid volatile ſalt afterwards paſſes over, which cryſtallizes in ſmall white or yellowiſh needles in the neck of the retort. This ſalt is ſucceeded by a white and light oil much reſembling naphta; by continuance of the proceſs, and in proportion as the heat is increaſed, the oily matter which comes over is coloured and more viſcid, like petroleum. What remains at the bottom of the retort is a black maſs reſembling aſphaltum. It appears, therefore, from diſtillation, that the analogy of amber with the other bitumens is very ſtrong.

A gentle heat is ſufficient to raiſe the concrete volatile ſalt of amber, and care muſt be taken to regulate it ſo as not to force up the oil, when it is required to have the ſalt in a ſeparate ſtate. This ſaline matter was for ſome time ſuppoſed to be an alkaline ſalt, but has been ſince found to be an acid of peculiar properties, and capable of combination with alkalies, earths, and metallic calces.

Amber is uſually dug out of the earth, and abounds particularly in the Pruſſian dominions. Wood is uſually found near it, and it is therefore believed to be of vegetable origin. Its analyſis ſeems to ſhew, that it conſiſts of an oil rendered concrete by combination with an acid. The moſt tranſparent ſpecimens are uſually found on the ſea-ſhore, particularly on the ſhores of the Baltic, in Ducal Pruſſia. Amber is not always of a yellow colour; it is ſometimes brown, ſometimes quite opake, and ſometimes black. Some have ſuppoſed that it is entirely of mineral origin, but this is diſproved by its diſtillation, and by the foreign bodies which are frequently contained in it, and which ſeem to demonſtrate that it was once in a fluid ſtate.

Hoffman and Newman ſay, that it is found upon the ſea-ſhore, or upon the ſurface of waters, particularly after great ſtorms, when it is collected by means of nets; but that the greater part of it is dug out of pits. The firſt ſtratum is ſand, then clay, then a layer of branches and trunks of trees, then a conſiderable quantity of pyrites, whence vitriol is prepared, and laſtly, a bed of ſand, through which the amber is diſperſed in ſmall pieces, or collected together in heaps. This account greatly favours the idea of the vegetable origin of amber; but Wallerius aſſerts, that the black and dark coloured amber is often found in the bowels of cetaceous fiſhes. M. Girtanner has a peculiar opinion on this ſubject; he thinks that amber is a vegetable oil rendered concrete by the acid of ants; it is that kind of ants called formica rufa by Linnæus, which prepares it, according to this author. Theſe inſects dwell in old foreſts of fir trees, where the foſſil amber is found, which, when firſt dug, is ductile like wax, and becomes hard on expoſure to air. No inſect is ſo commonly found in amber as the ant.

Ambergris is of much the ſame nature as amber, but differs from it by its particular conſiſtence, which nearly approaches to that of bees wax. Its ſtructure is ſometimes like bees wax, but ſometimes it is granulated, and appears opake, or of a dark grey. Experiments prove that it reſembles amber in its nature. When analyzed it is found to conſiſt of phlegm, a volatile acid partly fluid, oil, and a little coaly matter. It diſſolves more readily in ſpirit of wine than amber.

It is moſt common in the Indian ſeas, on the eaſtern coaſt of Africa, Madagaſcar, &c. and is found either floating on the ſea, or caſt on the ſea-ſhore. In this ſubſtance animal and vegetable remains are ſometimes found, as for inſtance, parts of birds, &c.

The origin of this ſubſtance is probably the ſame with that of amber. According to M. Aublet (in his *Hiſtoire de la Guiane)* it is nothing more than the juice of a tree inſpiſſated by evaporation; and if this is true, it is a ſubſtance which belongs properly to the vegetable kingdom. The tree which is ſaid to produce it grows in Guiana, and is called *cuma*, but has not been examined by other botaniſts. When a branch is broken by high winds, a large quantity of the juice exudes; and if it chances to have time to dry, various maſſes (ſome of which have been ſo large as to weigh one thouſand two hundred pounds and more) are carried into the rivers by heavy rains, and through them into the ſea; afterwards they are either thrown on the ſhore or eaten by ſome fiſh, chiefly the ſpermaceti whale, known by the name of *phyſiter-macrocephalus* among ichthyologiſts. This kind of whale is extremely voracious of this gum-reſin, and ſwallows ſuch large quantities when it meets with it, that it generally becomes ſick, ſo that thoſe employed in the fiſhery of theſe whales always expect to find ſome amber mixed with the excrements and remains of other food in the bowels of thoſe whales which are lean. Various authors, among whom is Father Santes, in his *Ethiopia Orientalis*, who travelled to various places on the African coaſt, and Bomare, ſay, that ſome ſpecies of birds are alſo fond of eating this ſubſtance, as well as whales and other fiſhes. This accounts very well for the claws, beaks, bones, and feathers of birds, parts of vegetables, ſhells, and bones of fiſh, and particularly for the beaks of the cuttle-fiſh, *ſepia octopedia*, which are ſometimes found in the maſs of this ſubſtance. M. Aublet brought ſpecimens of this gum-reſin, which he collected on the ſpot, from the cuma tree at Guiana. It is of a whitiſh brown colour, with a ſhade of yellow, and melts and burns like wax on the fire. M. Rouelle examined very carefully this ſubſtance, brought over by M. Aublet, and found that it produced exactly the ſame reſults as good amber.

Theſe obſervations ſeem to place it beyond a doubt, that both amber and ambergris are vegetable products, and that thoſe who, from having found theſe ſubſtances in the inteſtines of whales, concluded that it was a fæcal matter of thoſe animals, were miſtaken.

Mineral tallow is a very peculiar ſubſtance. It was found on the coaſts of Finland, in the year 1736. Its ſpecific gravity is 0.770, whereas that of tallow is 0.969. It burns with a blue flame and a ſmell of greaſe, leaving a black viſcid matter, which is more difficultly conſumed. It is found in ſome rocky parts of Perſia, but ſeems mixed with petroleum. Dr. Herman, of Straſburgh, mentions a ſpring, in the neighbourhood of that city, which contains a ſubſtance of that nature diffuſed through it, which ſeparates on ebullition, and may then be collected. The origin of this ſubſtance is unknown.

CHAP. XLII.

OF THE DIAMOND, CONSIDERED AS AN INFLAMMABLE SUBSTANCE.

Experiments proving the inflammable Nature of the Diamond.—Experiments of M. Cadet.—Of D'Arcet.—Vital Air neceſſary to the Combuſtion of the Diamond.—Experiments of Lavoiſier.—Further Experiments.—Concluſion from the whole.

THE external appearance of this peculiar and beautiful ſubſtance has been already deſcribed, but it is proper alſo to conſider it in another point of view, as from ſome extraordinary experiments many naturaliſts are diſpoſed to include it in the claſs of inflammables.

It has long been underſtood that diamonds, expoſed to a high degree of heat, entirely diſappear at the inſtant that an appearance of combuſtion is obſerved. M. Cadet expoſed diamonds in covered and luted * crucibles to the violent heat of a forge during two hours, by which the diamonds only loſt one ſixteenth part of their weight: he is of opinion, that the conſumption of diamonds in open veſſels is not a true volatilization, but merely an exfoliation occaſioned by the expanſion of the air contained between the laminæ of the diamond, by which it is broken into portions ſo minute as to eſcape obſervation. M. D'Arcet oppoſes to the above explanation, the eſcape of the ſubſtance of the diamonds through the moſt ſolid porcelain crucibles, and the luminous appearance noticed by Macquer, and which was afterwards obſerved by M. Roux to be an actual flame. It has, indeed, even been found, that diamonds incloſed in a ball of porcelain earth, and expoſed to heat, have been totally conſumed; the ſpace which the diamond occupied was found empty; no traces of it could be diſcovered, and yet the ball of porcelain, which was hardened by the heat, was apparently entire. This experiment, according to Fourcroy, has been frequently repeated with the ſame extraordinary reſult. It is found, however, that if the diamond is embedded in charcoal, and carefully incloſed in ſeveral crucibles placed within each other, and the whole covered with cement, it does not diſappear from expoſure to a very violent heat; it is only rendered black at its ſurface, and when this cruſt is taken off, it appears in its original ſplendor. It is therefore concluded, that perfect excluſion from vital air is ſufficient to prevent the conſumption of the diamond, as well as of all other inflammable ſubſtances; and it is therefore neceſſary to ſuppoſe, that the porcelain earth, in which other diamonds were incloſed, ſuffered ſome ſmall ſeparation from expoſure to heat, which, though ſo minute as to eſcape obſervation after the ball was cold, were yet ſufficient to admit the air. This opinion has been fully confirmed by ſome experiments of M. Lavoiſier, who found, that diamonds are only conſumed in proportion to the quantity of vital air to which they are expoſed. He alſo found, that the combuſtion of the diamond was attended with the formation of carbonic acid gas. This diſcovery may probably throw as much light on the nature of the diamond, as his other diſcoveries have diffuſed through almoſt the whole extent of natural ſcience. Some curious experiments on the diamond are alſo detailed in the Annales de Chimie for November 1791. A piece of iron wire was faſtened to the diamond intended to be burned, the iron was heated red hot, and in that ſtate plunged into a jar of vital air; the iron rook fire, and communicated the inflammation to the diamond, which burned in a moſt vivid manner, and with uncommon brightneſs. The Brazil diamonds, however, it is neceſſary to remark, could not be made to burn in this way. On the whole, there can be no doubt that the diamond is truly an inflammable ſubſtance; but a repetition of theſe expenſive experiments is neceſſary, in order accurately to aſcertain its nature, and to reconcile ſome differences in the reſults of ſuch experiments as have been already made.

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* Luting is a kind of earthy cement uſed by chemiſts, and formed in different ways.

CHAP. XLIII.

THE STRUCTURE OF THE EARTH.

The Curioſity of Man on this Topic limited by the Weakneſs of his Powers.—The Body of the Earth diſpoſed in Strata.—Declivities of Mountains—Diſpoſition and Order of the Strata.—Caldy Iſland.—Where Metals are uſually found.—Probable State of the Earth at its Creation.—Laws by which Alterations would be produced.—Foſſil Shells, &c. accounted for.—Formation of Iſlands, &c.—Other Irregularities of the Earth's Surface explained.

AFTER the preceding ſurvey of the natural contents of this globe of earth, and of their component principles, the next object of attention is the earth itſelf, and the general arrangement of thoſe ſubſtances of which it is compoſed. Theſe are neither diſpoſed in a regular ſeries, according to their ſpecific gravities, nor yet thrown together in total diſorder, as if by accident or chance. Human induſtry has hitherto been able to penetrate but a very little way into the bowels of the earth, and we can but know little of its interior parts. The depth of the earth, from the ſurface to the center, is more than four thouſand miles, and yet the deepeſt mine in Europe, that at Cotteberg, in Hungary, is not more than one thouſand yards deep; "the greateſt depth, therefore," ſays an excellent writer, "to which avarice has ever yet penetrated, may be compared to the puncture made in the body of an elephant by the proboſcis of a gnat."

From what has been diſcovered, however, of thoſe parts which lie moſt contiguous to our obſervation, naturaliſts have compared the ſtructure of the earth to the leaves of a book, or the coats of an onion. Except, indeed, in ſome of thoſe immenſe mountains, which have exiſted from the creation, or at leaſt from the deluge, where the matter, from whatever cauſe, is more homogeneous, the earth is found to conſiſt of various ſtrata, or layers, which differ according to the circumſtances of climate and ſituation. The ſurface, in general, evidently conſiſts of a confuſed mixture of decayed animal and vegetable ſubſtances and earths rudely united together; but when we have penetrated below the ſurface, we find the materials of the globe arranged in a more regular manner. Sometimes, indeed, we find heaps of ſtone, which do not conſiſt of layers, but are confuſed maſſes of unequal thickneſs, and are called rocks. The ſtrata are, in general, extended through a whole country, and, perhaps, with ſome interruptions and varieties, through the globe itſelf. Theſe extenſive bodies are found moſt regular when the country is flat, being, in that caſe, nearly parallel to the horizon, though frequently dipping downwards in a certain angle; in many places the beds have a wave, as where the country conſiſts of gently waving hills and vales; here too they generally dip. In travelling a mile we, perhaps, paſs through ground compoſed moſtly of ſand, in another mile we find it, perhaps, compoſed of clay; and this is occaſioned by the edges of the different ſtrata lying with an obliquity to the horizon. By the ſame kind of projection mountains, or ridges of mountains, are produced, which, in general, have what is called a back and a face, the former ſmoother and the latter more rugged. We generally find too, on one ſide of a mountain, a more gradual aſcent than on the other, which is occaſioned by the ſtrata, which have riſen above the general level of the country being abruptly broken off. Mountains are in general more abrupt towards the weſt, and have a more gentle declivity towards the eaſt; hence the weſtern coaſt of countries is almoſt always ſteeper than the eaſtern. The back of a mountain ſhews the obliquity with which the ſtrata ſink into the ground; the abrupt edge of the ſtrata becomes more ſloping, as time, producing a gradual decay, draws the rubbiſh from above. Where the face of a country is ſo irregular, its appearance depends on the different hardneſs or ſoftneſs of the ſtrata. The abrupt rocks, which we obſerve in many parts, ſeem to have been compoſed of an adventitious mixture of different ſtrata, which have reſiſted the injuries of time with unequal force.

Between the ſtrata, layers of different clays are interpoſed, which are called by the miners way-boards; they are ſeldom more than four or five, and in ſome inſtances not more than one foot thick; they ſerve to mark and diſtinguiſh the different ſtrata, for in fact the ſtrata are themſelves compoſed of different laminæ *.

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* Whitehurſt, Chap. XVI.

Every part of a ſtratum may be conſidered as equally thick when covered with an incumbent bed; but when expoſed to the action of the air, and other external agents, a great part of it, whether grit, limeſtone, or toad-ſtone, is decompoſed and converted into earth or mould. Immediately under the ſoil the fragments of ſtone are ſmall, and gradually increaſe to the depth of fifteen or twenty feet, where it commonly appears ſolid, and fit for the maſon. Strata are uſually interrupted by clefts or fiſſures at different diſtances, which ſeem to have been the effects of violence. In theſe fiſſures only the ores of metals are to be found.

It has been remarked, that we cannot, by digging into the earth, obtain a view of the poſition and nature of the ſtrata for more than ſome few hundreds of yards. There is, however, one curious inſtance of an iſland, near the coaſt of Pembrokeſhire, called Caldy Iſland, where the earth ſuffered the action of ſo unuſual a diſruption, that the ſtrata, of which the whole iſland is compoſed, are placed in a vertical poſition, ſo that their edges are all expoſed to view, and they may be obſerved in ſucceſſion from one end of the iſland to the other. Here then we have the ſingular opportunity of obſerving in what order they were originally placed, to the depth of two miles. At one end of the iſland they are not more than a foot thick, but increaſe, as we proceed, till they terminate in a ſtratum of red ſtone, more than a mile in thickneſs, which, with good reaſon, is ſuppoſed to have been the loweſt of them all before they were elevated and thrown upon their edges. The thinner ſtrata, which were originally uppermoſt, have foſſil ſhells and corallines in them; but I have not heard that any thing like the traces of lava are to be found to countenance the ſuppoſition, that this ſingular accident was occaſioned by the exploſive force of a volcano.

The order of the ſtrata in Derbyſhire is as follows: 1. Millſtone-grit, a coarſe ſand-ſtone compoſed of granulated quartz and quartz pebbles. 2. Shale or ſhiver, or black laminated clay, much indurated. 3. Lime-ſtone, in various laminæ. 4. Toad-ſtone, a black porous ſubſtance, hard, reſembling ſcoriæ, and apparently a volcanic production. 5. Lime-ſtone. 6. Toad-ſtone. 7. Lime-ſtone. 8. Toad-ſtone. 9. Lime-ſtone again. Such (the toad-ſtone excepted) appears to be the general order in which the ſtrata appear through the different regions of the earth, or at leaſt wherever the lime-ſtone predominates, which is in a conſiderable proportion, though it muſt be remarked that the largeſt mountains are chiefly granite. Wherever, therefore, the firſt of theſe ſtrata appears on the ſurface, the ſecond lies certainly under it, the third under the ſecond, &c. ſtill excepting the toad-ſtone, which, being a volcanic production, may be ſuppoſed to be in ſome meaſure caſually interpoſed.

The toad-ſtone interſects all the mineral veins, and cuts off all communication between the upper and lower parts of the fiſſures, being continued horizontally in one uninterrupted maſs. Toad-ſtone is of an extremely hard and cloſe texture, ſo much ſo as even to prevent water from filtering through it, at leaſt in any quantity. It is perfectly ſimilar to Iceland lava in appearance, and in being unaſſailable by acids. It has no fiſſures, and frequently fills up the fiſſures of the other ſtrata; in fine, it being not univerſal, but only an occaſional appearance, there is the utmoſt probability that it is a ſpecies of lava. It being inſerted between the other ſtrata ſeems alſo to afford a proof, that it originally flowed from a volcano, the funnel or ſhaft of which did not approach the open air, but diſcharged its fiery contents between the ſtrata in all directions. When the toadſtone is dug through, however, and the vein or fiſſure purſued, the miner is never diſappointed in meeting it again, as ſoon as he arrives at the ſtratum of lime-ſtone *.

The ſtrata of coal, argillaceous ſtones, clay, &c. are always incumbent on the ſtrata of grit, ſhale, and lime-ſtone. The former are ſeldom in ſtrata of above twenty feet thick, and generally not more than four or five; the latter are in ſtrata of from fifty to one hundred and fifty feet in thickneſs or depth †.

All beds of gravel are ſuppoſed to have been depoſited either by rivers or by the action of the ſea, and the ſtones that compoſe them to have been rounded by attrition. It is no inconſiderable proof in favour of ſuch a conjecture, that ſea ſhells, &c. are ſo frequently found with gravel.

The argillaceous ſtrata are only productive of iron and coal. The ores of copper, lead, zinc, &c.

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* Whitehurſt, Chap. XVI.

† Ib.

are confined entirely to the lime-ſtone ſtrata, a few inſtances excepted, where they are found in ſhale.

The diſpoſition of the ſuperficial ſtrata, however, differs in mountainous and champaign countries. ‘ In a well which was dug at Amſterdam, to the depth of two hundred and thirty feet, the following ſubſtances were found in ſucceſſion ; ſeven feet of vegetable earth, nine of turf, nine of ſoft clay, eight of ſand, four of earth, ten of clay, four of earth, ten of ſand, two of clay, four of white ſand, one of ſoft earth, fourteen of ſand, eight of clay mixed with ſand, four of ſea-ſand mixed with ſhells, then an hundred and two feet of ſoft clay, and then thirty-one feet of ſand.

‘ In a well dug at Marly, to the depth of an hundred feet, M. Buffon gives us a ſtill more exact enumeration of its layers of earth. Thirteen feet of a reddiſh gravel, two of gravel mingled with a vitrifiable ſand, three of mud or ſlime, two of marle, four of marly ſtone, five of marle in duſt mixed with vitrifiable ſand, ſix of very fine vitrifiable ſand, three of earthy marle, three of hard marle, one of gravel, one of eglantine, a ſtone of the hardneſs and grain of marble, one of gravelly marle, one of ſtony marle, one of a coarſer kind of ſtony marle, two of a coarſer kind ſtill, one of vitrifiable ſand mixed with foſſil ſhells, two of fine gravel, three of ſtony marle, one of coarſe powdered marle, one of ſtone, calcinable like marble, three of grey ſand, two of white ſand, one of red ſand ſtreaked with white, eight of grey ſand with

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* Varenius, as quoted by M. Buffon, p. 358.

ſhells, three of very fine ſand, three of a hard grey ſtone, four of red ſand ſtreaked with white, three of white ſand, and fifteen of reddiſh vitrifiable ſand.'

The direction too in which the ſtrata are found is alſo exceedingly different in different ſituations. 'When the continuity,' ſays Mr. Jones, 'of the ſtrata is interrupted by a fracture, the ſtrata are thrown out of that horizontal poſition which is natural to them, and make an angle with the horizon; which may be called the angle of their elevation or depreſſion; the miners call it their *dip*. In this caſe, if the ſucceſſion of ſtrata is accurately noted on one ſide of the fracture, where a vein of coal or metal is found amongſt them, it may thence be learned where the ſame vein will occur again on the other ſide of the fracture; becauſe it will be found adjacent to the ſame ſtrata as before. When the edges of the ſtrata, on each ſide a fiſſure, are thus parted and miſmatched, they are ſaid to *trap*; and the ſpace between them is filled up with rubble, or ſtones, or minerals, &c. Sometimes theſe fiſſures are the richeſt parts of the ſoil, containing ſuch matters as are not to be found elſewhere *. In fig. I. plate I. F. repreſents the fiſſure, by which the ſtrata are parted, and which is filled up with extraneous rubbiſh, carried in after the ſtrata were parted. The black vein of coal on the left ſide is found with five other ſtrata above it; but being interrupted by the fiſſure F. where it *comes out to the day*, the ſtratum of ſand, No. 4, on the right ſide, on account of the trapping, is found oppoſite to it: thence it is to be collected, that the fourth ſtratum below that ſand will be coal; and when the angle of the *dip* is obſerved, it may be known where to ſink a pit, and where the coal will again appear to the day; provided the figure of the ſurface of the ground will permit it to ſhew itſelf. When I was once at the bottom of a lead mine in Derbyſhire, a miner informed me, that the veins of the metal always make a greater angle with the horizon than the ſides of the mountain do, in which they are found and come out to the day; which was probably occaſioned by the deſcent of the waters of the flood, tearing away much of the matter from the ſummit, and lodging it upon the ſides and in the vallies beneath, after the ſtrata had received their inclination.'

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* Some of the fiſſures in Cornwall are near twenty feet over, and commonly full, or near it, of metallic and mineral matter. The fiſſures at the greateſt depth are generally largeſt: as we aſcend they become gradually leſs, but more frequent and numerous: inſomuch that if the globe was divided in two, and the ſtrata viewed upon the face of the ſection, the figures would appear after the manner of a tree: at the bottom a large trunk, which higher up is divided into branches, which break into

into leſſer, and at the top into twigs. But the branches are not continued in a ſtrait line: they ſtart afreſh, at ſome little diſtance on one ſide, as in fig. 2. that by an intervening boundary the metallic matter might be detained in its deſcent, and prevented from ſinking away to the bottom of the earth. See Mr. Hutchinſon's Obſervations in the year 1706, p. 316, 317.

With reſpect to the more internal parts of the earth, for the reaſons aſſigned in the beginning of this chapter, nothing can be advanced with certainty, and hypotheſes cannot be relied on.

By ſome it has been ſuppoſed, that the center of the earth conſiſts of fire. Mr. Kirwan, however, has ſatisfactorily proved, that the notion of a central fire or heat is void of foundation. Since no authentic obſervation aſſures us, that this heat increaſes in proportion as we penetrate below the ſurface of the earth; on the contrary, many experiments ſerve to evince, that it rather decreaſes (though never to leſs than thirty-ſix degrees) and that its variation at the ſame diſtance below the ſurface conſtantly bears a proportion with the variation of the ſolar heat at the ſurface.

The more general opinion is, that the ſtrata originally lay horizontally, and were formed by a depoſition from water. The arguments for this opinion are forcible. The relics of a variety of ſubſtances, which we now find only in the ſea, are found in rocks and mountains, at a very great diſtance from it. In ſtrata of lime-ſtone, every where diſtant from the ſea, we find the remains of ſhells, &c. the productions of the ocean. Other circumſtances prove, that the ſea has covered parts of the earth, which are now at a great diſtance from it, and that the various directions which the ſtrata now have were not their direction at their firſt formation. That the frame of this earth has undergone ſome violent concuſſion is evident, as was already ſtated, from the traces which ſtill remain. The ſtrata we have ſeen are often broken in different directions, in general perpendicularly; ſo that the parts of the ſtrata are ſeparated from each other. The width of theſe rents is different, ſometimes a few inches, ſometimes many yards. They are very commonly filled up with ſubſtances different from the compoſition of the ſtrata. In mountains there is ſometimes obſerved the appearance of a white ſtone, which paſſes through it like a vein. This has been a rent filled up with a particular kind of ſtone. Theſe are very common in the ſtrata of coal. They are generally of conſiderable hardneſs, and in them metallic ſubſtances are uſually found. When any of theſe are not filled up with extraneous matter, the internal ſurface is ſet with very beautiful and regular cryſtals of the ſparry kind, projecting into the cavity.

Some have attributed theſe irregularities to frequent earthquakes; others have imagined that the globe, before the deluge, contained an immenſe body of water, covered over with a cruſt of earth, which at the deluge was broken through, and partly ſunk in the waters, the elevated edges forming the mountains and high lands, while the lower were overflowed by the ocean; others have ſuppoſed, that the near approach of a comet has thrown the materials of the globe into confuſion. Buffon imagines, that the ſea is continually changing its bed, and is conſtantly waſhing away the ground from one place to another*. But the arguments and obſervations of Mr. Whitehurſt are more deſerv- ing attention, ſince he is almoſt the only writer on

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* A ſhort ſketch of the moſt remarkable theories of the earth is given by a popular writer, and it may be amuſing to

to ſome readers to trace theſe vagaries of the human imagination.

‘ The firſt who formed this amuſement of earth-making into ſyſtem was the celebrated Thomas Burnet, a man of polite learning and rapid imagination. His *Sacred Theory*, as he calls it, deſcribing the changes which the earth has undergone, or ſhall hereafter undergo, is well known for the warmth with which it is imagined, and the weakneſs with which it is reaſoned, for the elegance of its ſtyle, and the meanneſs of its philoſophy. The earth, ſays he, before the deluge, was very differently formed from what it is at preſent: it was at firſt a fluid maſs; a chaos compoſed of various ſubſtances, differing both in denſity and figure: thoſe which were moſt heavy ſunk to the center, and formed in the middle of our globe an hard ſolid body; thoſe of a lighter nature remained next; and the waters, which were lighter ſtill, ſwam upon its ſurface, and covered the earth on every ſide. The air, and all thoſe fluids which were lighter than water, floated upon this alſo; and in the ſame manner encompaſſed the globe; ſo that between the ſurrounding body of waters, and the circumambient air, there was formed a coat of oil, and other unctuous ſubſtances, lighter than water. However, as the air was ſtill extremely impure, and muſt have carried up with it many of thoſe earthy particles with which it once was intimately blended, it ſoon began to defecate, and to depoſe theſe particles upon the oily ſurface already mentioned, which ſoon uniting, the earth and oil formed that cruſt, which ſoon became an habitable ſurface, giving life to vegetation, and dwelling to animals.

‘ This imaginary antideluvian abode was very different from what we ſee it at preſent. The earth was light and rich; and formed of a ſubſtance entirely adapted to the feeble ſtate of incipient vegetation: it was an uniform plain, every where covered with verdure; without mountains, without ſeas, or the ſmalleſt inequalities. It had no difference of ſeaſons, for its equator was in the plain of the ecliptic, or, in other words, it on this ſubject, who has united obſervation with theory.

With

it turned directly oppoſite to the ſun, ſo that it enjoyed one perpetual and luxuriant ſpring. However, this delightful face of nature did not long continue in the ſame ſtate, for, after a time, it began to crack and open in fiſſures: a circumſtance which always ſucceeds when the ſun exhales the moiſture from rich or marſhy ſituations. The crimes of mankind had been for ſome time preparing to draw down the wrath of Heaven; and they, at length, induced the Deity to defer repairing theſe breaches in nature. Thus the chaſms of the earth every day became wider, and, at length, they penetrated to the great abyſs of waters; and the whole earth, in a manner, fell in. Then enſued a total diſorder in the uniform beauty of the firſt creation, the terrene ſurface of the globe being broken down: as it ſunk the waters guſhed out in its place; the deluge became univerſal; all mankind, except eight perſons, were deſtroyed, and their poſterity condemned to toil upon the ruins of deſolated nature.

'It only remains to mention the manner in which he relieves the earth from this univerſal wreck, which would ſeem to be as difficult as even its firſt formation. "Theſe great maſſes of earth falling into the abyſs, drew down with them vaſt quantities alſo of air; and by daſhing againſt each other, and breaking into ſmall parts by the repeated violence of the ſhock, they, at length, left between them large cavities filled with nothing but air. Theſe cavities naturally offered a bed to receive the influent waters; and in proportion as they filled, the face of the earth became once more viſible. The higher parts of its broken ſurface, now become the tops of mountains, were the firſt that appeared; the plains ſoon after came forward, and, at length, the whole globe was delivered from the waters, except the places in the loweſt ſituations; ſo that the ocean and the ſeas are ſtill a part of the ancient abyſs that have not had a place to return to. Iſlands and rocks are fragments of the earth's former cruſt; kingdoms and continents are larger maſſes of its broken ſubſtance; and all the inequalities that are to be

found

With reſpect to the form of the earth, it is now ſcarcely neceſſary to mention, that it is nearly round;

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found on the ſurface of the preſent earth, are owing to the accidental confuſion into which both earth and waters were then thrown."

' The next theoriſt was Woodward, who, in his Eſſay towards a Natural Hiſtory of the Earth, which was only deſigned to precede a greater work, has endeavoured to give a more rational account of its appearances; and was, in fact, much better furniſhed for ſuch an undertaking than any of his predeceſſors, being one of the moſt aſſiduous naturaliſts of his time. His little book, therefore, contains many important facts, relative to natural hiſtory, although his ſyſtem may be weak and groundleſs.

' He begins by aſſerting that all terrene ſubſtances are diſpoſed in beds of various natures, lying horizontally one over the other, ſomewhat like the coats of an onion; that they are replete with ſhells, and other productions of the ſea: theſe ſhells being found in the deepeſt cavities, and on the tops of the higheſt mountains. From theſe obſervations, which are warranted by experience, he proceeds to obſerve, that theſe ſhells and extraneous foſſils are not productions of the earth, but are all actual remains of thoſe animals which they are known to reſemble; that all the beds of the earth lie under each other, in the order of their ſpecific gravity; and that they are diſpoſed as if they had been left there by ſubſiding waters. All theſe aſſertions he affirms with much earneſtneſs, although daily experience contradicts him in ſome of them; particularly we find layers of ſtone often over the lighteſt ſoils, and the ſofteſt earth under the hardeſt bodies. However, having taken it for granted, that all the layers of the earth are found in the order of their ſpecific gravity, the lighteſt at the top, and the heavieſt next the center, he conſequently aſſerts, and it will not improbably follow, that all the ſubſtances of which the earth is compoſed were once in an actual ſtate of diſſolution. This univerſal diſſolution he takes to have happened at the time of the flood. He ſuppoſes that at that time a body of water, which was then in round; a circumſtance, however, which, though now ſo univerſally known, remained undiſcovered for

many

in the center of the earth, uniting with that which was found on the ſurface, ſo far ſeparated the terrene parts as to mix all together in one fluid maſs; the contents of which afterwards ſinking according to their reſpective gravities, produced the preſent appearances of the earth. Being aware, however, of an objection that foſſil ſubſtances are not found diſſolved, he exempts them from this univerſal diſſolution, and, for that purpoſe, endeavours to ſhew that the parts of animals have a ſtronger coheſion than thoſe of minerals; and that, while even the hardeſt rocks may be diſſolved, bones and ſhells may ſtill continue entire.

‘ So much for Woodward; but of all the ſyſtems which were publiſhed reſpecting the earth's formation, that of Whiſton was moſt applauded, and moſt oppoſed. Nor need we wonder; for being ſupported with all the parade of deep calculation, it awed the ignorant, and produced the approbation of ſuch as would be thought otherwiſe, as it implied a knowledge of abſtruſe learning, to be even thought capable of comprehending what the writer aimed at. In fact, it is not eaſy to diveſt this theory of its mathematical garb; but thoſe who have had leiſure, have found the reſult of our philoſopher's reaſoning to be thus. He ſuppoſes the earth to have been originally a comet; and he conſiders the hiſtory of the creation, as given us in ſcripture, to have its commencement juſt when it was, by the hand of the Creator, more regularly placed as a planet in our ſolar ſyſtem. Before that time, he ſuppoſes it to have been a globe without beauty or proportion; a world in diſorder; ſubject to all the viciſſitudes which comets endure; ſome of which have been found, at different times, a thouſand times hotter than melted iron; at others, a thouſand times colder than ice. Theſe alternations of heat and cold, continually melting and freezing the ſurface of the earth, he ſuppoſes to have produced, to a certain depth, a chaos entirely reſembling that deſcribed by the poets, ſurrounding the ſolid contents of the earth, which ſtill continued

unchanged

many thouſand years. That its form is ſpherical, was firſt conjectured from the curved line which bounds

unchanged in the midſt, making a great burning globe of more than two thouſand leagues in diameter. This ſurrounding chaos, however, was far from being ſolid: he reſembles it to a denſe though fluid atmoſphere, compoſed of ſubſtances mingled, agitated, and ſhocked againſt each other; and in this diſorder he deſcribes the earth to have been juſt at the eve of creation.

'But upon its orbit's being then changed, when it was more regularly wheeled round the ſun, every thing took its proper place; every part of the ſurrounding fluid then fell into a ſituation, in proportion as it was light or heavy. The middle, or central part, which always remained unchanged, ſtill continued ſo, retaining a part of that heat which it received in its primæval approaches towards the ſun; which heat, he calculates, may continue for about ſix thouſand years. Next to this fell the heavier parts of the chaotic atmoſphere, which ſerve to ſuſtain the lighter: but as in deſcending they could not entirely be ſeparated from many watery parts, with which they were intimately mixed, they drew down a part of theſe alſo with them; and theſe could not mount again after the ſurface of the earth was conſolidated: they, therefore, ſurrounded the heavy firſt deſcending parts, in the ſame manner as theſe ſurround the central globe. Thus the entire body of the earth is compoſed internally of a great burning globe: next which is placed an heavy terrene ſubſtance, that encompaſſes it; round which alſo is circumfuſed a body of water. Upon this body of water, the cruſt of earth on which we inhabit is placed: ſo that, according to him, the globe is compoſed of a number of coats, or ſhells, one within the other, all of different denſities. The body of the earth being thus formed, the air, which is the lighteſt ſubſtance of all, ſurrounded its ſurface; and the beams of the ſun darting through, produced that light which, we are told, firſt obeyed the Creator's command.

'The whole œconomy of the creation being thus adjuſted, it only remained to account for the riſings and depreſſions on the ſurface of the earth, with the other ſeeming irregularities of bounds the earth's ſhadow in lunar eclipſes. We have a ſtill plainer proof of its rotundity, from the appearance

of its preſent appearance. The hills and vallies are conſidered by him as formed by their preſſing upon the internal fluid, which ſuſtains the outward ſhell of earth, with greater or leſs weight: thoſe parts of the earth which are heavieſt, ſink into the ſubjacent fluid more deeply, and become vallies: thoſe that are lighteſt, riſe higher upon the earth's ſurface, and are called mountains.

'Such was the face of nature before the deluge; the earth was then more fertile and populous than it is at preſent; the life of man and animals were extended to ten times its preſent duration; and all theſe advantages aroſe from the ſuperior heat of the central globe, which ever ſince has been cooling.' As its heat was then in full power, the genial principle was alſo much greater than at preſent; vegetation and animal increaſe were carried on with more vigour; and all nature ſeemed teeming with the ſeeds of life. But theſe phyſical advantages were only productive of moral evil; the warmth which invigorated the body encreaſed the paſſions and appetites of the mind; and, as man became more powerful, he grew leſs innocent. It was found neceſſary to puniſh this depravity; and all living creatures were overwhelmed by the deluge in univerſal deſtruction.

'This deluge, which ſimple believers are willing to aſcribe to a miracle, philoſophers have been long deſirous to account for by natural cauſes: they have proved that the earth could never ſupply from any reſervoir towards its center, nor the atmoſphere by any diſcharge from above, ſuch a quantity of water as would cover the ſurface of the globe to a certain depth over the tops of our higheſt mountains. Where, therefore, was all this water to be found? Whiſton has found enough, and more than a ſufficiency, in the tail of a comet; for he ſeems to allot comets a very active part in the great operations of nature.

'He calculates with great ſeeming preciſion, the year, the month, and the day of the week on which this comet (which has paid the earth ſome viſits ſince, though at a kinder diſtance) involved

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appearance of objects on the ſurface of the earth, but ſtill more remarkably on that of the ſea. As

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involved our globe in its tail. The tail he ſuppoſed to be a vapourous fluid ſubſtance, exhaled from the body of the comet, by the extreme heat of the ſun, and increaſing in proportion as it approached that great luminary. It was in this that our globe was involved at the time of the deluge; and, as the earth ſtill acted by its natural attraction, it drew to itſelf all the watery vapours which were in the comet's tail; and the internal waters being alſo at the ſame time let looſe, in a very ſhort ſpace the tops of the higheſt mountains were laid under the deep.

The puniſhment of the deluge being thus completed, and all the guilty deſtroyed, the earth, which had been broken by the eruption of the internal waters, was alſo enlarged by it; ſo that upon the comet's receſs, there was found room ſufficient in the internal abyſs for the receſs of the ſuperfluous waters; whither they all retired, and left the earth uncovered, but in ſome reſpects changed, particularly in its figure, which, from being round, was now become oblate. In this univerſal wreck of nature Noah ſurvived, by a variety of happy cauſes, to re-people the earth, and to give birth to a race of men ſlow in believing ill-imagined theories of the earth.

After ſo many theories of the earth, which had been publiſhed, applauded, anſwered, and forgotten, M. Buffon ventured to add one more to the number. This philoſopher was in every reſpect better qualified than any of his predeceſſors for ſuch an attempt, being furniſhed with more materials, having a brighter imagination to find new proofs, and a better ſtyle to cloath them in. However, if one ſo ill qualified as I am may judge, this ſeems the weakeſt part of his admirable work; and I could wiſh that he had been content with giving us facts inſtead of ſyſtems; that, inſtead of being a reaſoner, he had contented himſelf with being merely an hiſtorian.

He begins his ſyſtem by making a diſtinction between the firſt part of it and the laſt; the one being founded only on conjecture, the other depending entirely upon actual obſervation.

we depart from objects on the ocean, they ſeem to ſubſide gradually below the viſible horizon. Ships at

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The latter part of his theory may, therefore, be true, though the former ſhould be found erroneous.

The planets, ſays he, and the earth among the number, might have been formerly (he only offers this as conjecture) a part of the body of the ſun, and adherent to its ſubſtance. In this ſituation, a comet falling in upon that great body might have given it ſuch a ſhock, and ſo ſhaken its whole frame, that ſome of its particles might have been driven off like ſtreaming ſparkles from red hot iron; and each of theſe ſtreams of fire, ſmall as they were in compariſon of the ſun, might have been large enough to have made an earth as great, nay many times greater than ours. So that in this manner the planets, together with the globe which we inhabit, might have been driven off from the body of the ſun by an impulſive force: in this manner alſo they would continue to recede from it for ever, were they not drawn back by its ſuperior power of attraction; and thus, by the combination of the two motions, they are wheeled round in circles.

Being in this manner detached at a diſtance from the body of the ſun, the planets, from having been at firſt globes of liquid fire, gradually became cool. The earth alſo having been impelled obliquely forward, received a rotatory motion upon its axis at the very inſtant of its formation; and this motion being greateſt at the equator, the parts there acting againſt the force of gravity, they muſt have ſwollen out, and given the earth an oblate or flatted figure.

As to its internal ſubſtance, our globe having once belonged to the ſun, it continues to be an uniform maſs of melted matter, very probably vitrified in its primæval fuſion. But its ſurface is very differently compoſed. Having been in the beginning heated to a degree equal to, if not greater, than what comets are found to ſuſtain, like them it had an atmoſphere of vapours floating round it, and which, cooling by degrees, condenſed and ſubſided upon its ſurface. Theſe vapours formed, according to their different denſities, the earth, the water, and the

at a diſtance on the water are not viſible in their hulls; at a greater diſtance, their mainſails diſap-
pear;

the air; the heavier parts falling firſt, and the lighter remaining ſtill ſuſpended.

Thus far our philoſopher is, at leaſt, as much a ſyſtem-maker as Whiſton or Burnet; and, indeed, he fights his way with great perſeverance and ingenuity through a thouſand objections that naturally ariſe. Having, at laſt, got upon the earth, he ſuppoſes himſelf on firmer ground, and goes forward with greater ſecurity. Turning his attention to the preſent appearance of things upon this globe, he pronounces from the view that the whole earth was at firſt under water. This water he ſuppoſes to have been the lighter parts of its former evaporation, which, while the earthy particles ſunk downwards by their natural gravity, floated on the ſurface, and covered it for a conſiderable ſpace of time.

“ The ſurface of the earth,” ſays he *, “ muſt have been in the beginning much leſs ſolid than it is at preſent; and, conſequently, the ſame cauſes, which at this day produce but very ſlight changes, muſt then, upon ſo complying a ſubſtance, have had very conſiderable effects. We have no reaſon to doubt but that it was then covered with the waters of the ſea; and that thoſe waters were above the tops of our higheſt mountains, ſince, even in ſuch elevated ſituations, we find ſhells and other marine productions in very great abundance. It appears alſo that the ſea continued for a conſiderable time upon the face of the earth: for as theſe layers of ſhells are found ſo very frequent at ſuch great depths, and in ſuch prodigious quantities, it ſeems impoſſible for ſuch numbers to have been ſupported all alive at one time; ſo that they muſt have been brought there by ſucceſſive depoſitions. Theſe ſhells alſo are found in the bodies of the hardeſt rocks, where they could not have been depoſited all at once, at the time of the deluge, or at any ſuch inſtant revolution; ſince that would be to ſuppoſe, that all the rocks in which they are found were, at that inſtant, in a ſtate of diſſo-

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* Theorie de la Terre, vol. i. p. 111.

pear; and at a greater ſtill, their topſails; which could not be, if they ſailed on a plain. But that the earth is really globular was at length practically demonſtrated by the adventurous project of ſailing round it, which has ſeveral times been effected.

This fact being premiſed, let us conſider in what manner the known laws of nature were likely to act upon a maſs of materials ſuch as enter into the compoſition of this globe.

The firſt principle of the law of gravitation is, that the conſtituent particles of all bodies attract each

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lution, which would be abſurd to aſſert. The ſea, therefore, depoſited them where ever they are now to be found, and that by ſlow and ſucceſſive degrees.

"It will appear, alſo, that the ſea covered the whole earth, from the appearance of its layers, which lying regularly one above the other, ſeem all to reſemble the ſediment formed at different times by the ocean. Hence, by the irregular force of its waves, and its currents driving the bottom into ſand-banks, mountains muſt have been gradually formed within this univerſal covering of waters; and theſe ſucceſſively raiſing their heads above its ſurface, muſt, in time, have formed the higheſt ridges of mountains upon land, together with continents, iſlands, and low grounds, all in their turns. This opinion will receive additional weight by conſidering, that in thoſe parts of the earth where the power of the ocean is greateſt, the inequalities on the ſurface of the earth are higheſt: the ocean's power is greateſt at the equator, where its winds and tides are moſt conſtant; and, in fact, the mountains at the equator are found to be higher than in any other part of the world. The ſea, therefore, has produced the principal changes in our earth: rivers, volcanoes, earthquakes, ſtorms, and rain, having made but ſlight alterations, and only ſuch as have affected the globe to very inconſiderable depths."

GOLDSMITH'S *Hiſtory of the Earth and Animated Nature,* VOL. I. p. 22, &c.

other mutually, whence ariſe their common centers of gravity. Hence all fluids aſſume a ſpherical form, from the particles mutually attracting each other; and no bodies but fluids being capable of obeying the laws of gravitation, ſo as to become ſpherical, it is preſumed that the earth was originally in a fluid ſtate. The earth revolves round its center, and the centrifugal force increaſes in proportion to the diſtance from the axis of motion; all bodies, therefore, revolving round their axis in a ſtate of fluidity, will neceſſarily depart from the ſpherical form, and aſſume that of an oblate ſpheroid. Such, by actual menſuration, is found to be the form of the earth; and this is alſo demonſtrated, by aſtronomical obſervations, to be the caſe with all the other planets. It is therefore highly probable, that all theſe bodies were originally fluid, and only departed in ſome meaſure from the ſpherical form, in conſequence of a revolution on their axis.

It is not natural or eaſy to ſuppoſe, that the earth and planets have, ſince their exiſtence, been reduced, by any ſolvent principle, from a ſolid to a fluid ſtate. It is much more obvious to believe, that ſuch was their ſtate at their firſt creation. It follows of conſequence, that they had a beginning, and have not exiſted from eternity, as ſome fantaſtical writers have been inclined to imagine.

If ſuch was the original ſtate of the earth, it follows, that it was at firſt abſolutely unfit for animal and vegetable life; and, therefore, theſe muſt have been after-creations. This account, it is obſervable, agrees admirably with the Moſaic account of the creation, as well as with the opinions of the moſt ancient philoſophers, hiſtorians, poets, &c. that is, with the traditions of the firſt ages.

It is the opinion of Mr. Whitehurſt, that the component parts of the earth, at its firſt formation, exiſted in a ſtate of actual ſolution, and that they ſubſided partly into ſolid bodies, and partly into fluids, by the mutual action of theſe particles upon each other.

We have ſeen that there exiſts between different particles of matter what is called elective or chemical attraction, by which ſubſtances having certain properties in common are diſpoſed to unite; and by the combinations thus formed (whether by an immediate act of omnipotence, or whether by ſome more gradual proceſs) the ſuſpenſion of the component parts of the chaotic maſs would be effectually deſtroyed, and bodies would approach towards their center of gravity in proportion to their reſpective denſities. That the laws of elective attraction have prevailed in the formation of the earth is evident from the ſameneſs of quality which is obſerved in different ſtrata of minerals.

It has been, I think, demonſtrated, that the preſence of heat or fire is the efficient cauſe of fluidity. When the permanently elaſtic fluids, therefore, which conſtitute the atmoſphere, aſſumed their aeriform ſtate, and roſe from the chaotic maſs, a great quantity of heat muſt have become latent, while the remaining ſubſtances, from which the heat was abſtracted, muſt have been conſiderably cooled, and it might, therefore, be expected, that thoſe kinds of matter, which had leaſt attraction for heat, would aſſume a ſolid form; while others, whoſe attraction for that ſubſtance was intermediate, would remain in the ſtate of common fluids. It is, therefore, perfectly agreeable to ſound philoſophy to ſuppoſe, that the abſtraction of a conſiderable quantity of caloric, or the matter of fire, from the chaotic maſs, would effectually deſtroy its fluidity, and would almoſt inſtantly produce all the different mineral ſubſtances, which are obſerved in the bowels of the earth. Not that we are under any neceſſity of believing, that the whole internal ſubſtance of the earth exiſts at this hour as it exiſted when creation was completed. There are a variety of proceſſes going on continually in the interior parts of the globe, beſide thoſe more ſudden and violent changes, which have been produced by earthquakes, floods, and volcanoes.

By the ſubſiding of the denſer and more ſolid bodies, a conſiderable portion of the fluid matter would be left in a ſeparate ſtate, and would form large maſſes, or oceans of water.

With reſpect to the formation of iſlands, nothing more was neceſſary than the unequal and irregular ſubſiding of the different parts of matter, which may have happened from a variety of cauſes; from the effects of elective attraction and cryſtallization; from the motion of the earth, and the flux and reflux of the tides. The latter cauſe would neceſſarily remove the ſolid maſſes, as they were formed, from place to place, till theſe ſolid maſſes, meeting with others, or increaſing their bulk by their action upon congenial particles, would, from their increaſed gravity and denſity, at length become ſtationary. Thus the ſurface of the earth is all irregular, and an iſland is no other than a hill or mountain, the adjacent vallies of which are filled with water. Some iſlands, however, we know, are of more recent origin. Some have been thrown up by volcanic eruptions; and ſome have apparently been formed by that extraordinary inſect which produces rocks of coral. The iſlands Delos and Rhodes are ſaid to have *grown* out of the ſea. Pliny mentions a number of other iſlands, which were produced by ſubterraneous fires. In 1628, one of the iſlands of the Azores roſe up out of the bottom of the ſea, which in that place was one hundred and ſixty fathoms deep; and this iſland, which is three leagues long, one league and an half broad, and three hundred and ſixty feet above the level of the water, roſe in fifteen days*.

On the 20th of November, 1720, a ſubterraneous fire burſt out of the ſea near Tercera, one of the Azores, which threw up ſuch a quantity of ſtones, in the ſpace of thirty days, as formed an iſland two leagues in diameter, and nearly circular†.

The Iſle of Sheppey contains a great variety of foſſil bodies, as well animal as vegetable, which evidently prove it to be an aſſemblage of adventitious matter.

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* Sir William Hamilton's Obſervations on Veſuvius and Ætna.

† Philoſophical Tranſactions, quoted by Whitehurſt.

In every inſtance upon record, the fragments of ſea ſhells are infinitely more numerous than the bones and teeth of fiſh. The latter too are but ſeldom depoſited in any other matter than in beds of ſand and gravel, and not in the ſolid beds of lime-ſtone, as the ſhells of fiſh generally are, even to the depth of many hundred yards, and diſpoſed throughout the whole extent of the ſtrata *.

There is no occaſion to ſuppoſe, that the whole ſurface of the earth was at once rendered habitable. From the ſcripture account we have reaſon to believe, that only a very ſmall part of it was inhabited for a long ſeries of time, *viz.* the regions about the Euphrates, ſuppoſed to conſtitute the Garden of Eden. Here the terreſtrial animals were chiefly aſſembled, while the marine animals were diſperſed through the great abyſs of waters; and, from the extreme fecundity of thoſe animals, they would, in a very ſhort ſpace of time "replenifh the waters" from pole to pole. If, therefore, we ſuppoſe (as is moſt probable) that the greater part of the earth was gradually forming itſelf according to the laws of nature and creation, in other words, according to the uſual proceſſes of attraction and combination, it is eaſy to conceive, that a part of theſe animals, eſpecially thoſe which are leaſt active, would be gradually intombed in the increaſing maſs, and this will account for the great quantities of the exuviæ and bones of marine animals, eſpecially ſhell fiſh, which are found in beds of lime-ſtone, gravel, &c. even on the tops of mountains.

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* Whitehurſt, p. 44.

We ſhall ceaſe to be aſtoniſhed at the immenſe quantities of ſhells, which are thus found imbedded in the earth, if we only conſider the amazingly prolific nature of theſe animals. It is not uncommon to take away a bed of theſe ſhell fiſh ſeveral fathoms in thickneſs; and, though the places whence they are removed appear entirely exhauſted, yet in the enſuing ſeaſon there ſhall be as many found in all theſe places as there were before *.

The bones or teeth of fiſh, Mr. Whitehurſt affirms, as far as his knowledge extends, have never been found mixed with ſhells in the ſolid ſubſtance of lime-ſtone.

That at different periods the earth muſt have ſuffered very violent convulſions and diſcerptations of the ſolid parts, we may reaſonably conclude from the rugged and uncouth appearance of many of the mountainous parts of the world. We ſee rocks in ſome places torn aſunder, or, in appearance cut with a ſaw. Mr. Whitehurſt remarks, that at Stafford and Newport, in Shropſhire, there are detached blocks of Corniſh moor-ſtone, or granite, of conſiderable magnitude, though no ſuch ſtratum is known to exiſt nearer than Cornwall. It is fair, therefore, to conclude, that they have been thrown there by ſome violent commotion or ſubterraneous convulſion.

To the general deluge, that fact recorded with ſo much preciſion in the writings of Moſes, and confirmed by the traditions of every nation, we muſt

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* Whitehurſt, p. 47.

attribute much of the irregularities of the earth's ſurface. It would in ſome inſtances have the effect of reducing great maſſes of matter to a ſecond ſtate of ſolution. Many eminences would be levelled, and ſome of the vallies would be filled up. Some parts, which before were ſea, might receive ſuch an acceſſion of foreign matter as to fill up their beds, and on the ſubſiding of the waters to preſent to the eye a vaſt level plain. Thoſe elevations, on the contrary, which conſiſted of ſolid maſſes of the harder ſtones, would have the lighter portions of earth waſhed away from their baſes, and their height would receive a proportional increaſe. If pit coal, indeed, is of vegetable origin, it is difficult to account for the depoſition of ſuch a quantity of vegetable matter beneath the ſurface of the earth, on any other hypotheſis than that of a deluge; and though much of the exuviæ of ſhell-fiſh might be involved in the firſt ages ſucceeding the creation, in the manner Mr. Whitehurſt ſuppoſes, much greater quantities would be inhumed at the deluge. The other animal matters found in a foſſil ſtate, particularly the horns, ſkeletons, and bones of animals, which are much larger than any now found upon the earth, can only be accounted for upon this hypotheſis. Such are thoſe mentioned by Buffon, which were dug up in America, near the river Ohio, a ſingle tooth of which, belonging to a large row, weighed upwards of eleven pounds, and a ſingle thigh bone was upwards of four feet in length. In the year 1783, a ſkeleton of an immenſe animal of the deer kind was found on an eſtate belonging to Dr. Percy, Biſhop of Dromore. It was dug out of a marle pit, under a peat moſs, and was found ſurrounded by ſhells and other marine productions. The horns were ſeven feet and one inch in height, the length of the ſkull nearly two feet, the breadth of the forehead nearly a foot, and the bones of an enormous ſize. In Siberia, in America, and even in England, the bones and teeth of the elephant, hippopotamus, and other animals, which never have exiſted in thoſe climates, have been found, and even theſe were larger than thoſe of any ſuch animals now exiſting.

To the deluge, therefore, much of the preſent inequalities of the earth may be rationally attributed. But there are other cauſes which may have operated both before and ſince. It is a fact, which will ſcarcely admit of diſpute, that volcanic eruptions were much more frequent in the early ages of the world than at preſent; the veſtiges of volcanoes, and, even the exhauſted craters, are often found, where there is now not the leaſt appearance of ſubterraneous fire. This fact is alſo eaſily accounted for on philoſophical principles. The imperfect, and, if I may ſo ſpeak, accidental mixture of different bodies, would in many caſes produce ſpontaneous inflammation in the early ages of the world, whereas, as the earth grows older, theſe materials muſt be exhauſted, or rather formed into other combinations. Many mountains, we know, are of volcanic origin, and therefore many of them of a date long poſterior to the æra of creation.

Such appears to be the moſt rational account of the ſtructure of the earth, as far as we are warranted by actual experiment, or well authenticated obſervation. The ſucceeding chapters of this book will ſerve to explain more ſatisfactorily the different appearances of different portions of the globe. I ſhall therefore proceed, without further digreſſion, to treat more particularly of mountains, volcanoes, and the other phenomena more immediately connected with this branch of natural hiſtory.

CHAP. XLIV.

MOUNTAINS.

Diſtinction between Hills and Mountains.—Mountains primæval or ſecondary.—Granite Mountains only ſuppoſed in general primæval.—Some lime-ſtone Mountains primæval.—Alluvial Mountains.—Entire and ſtratified Mountains.—Mountains homogeneous and heterogeneous.—Confuſed Mountains.—Volcanic Mountains.—Height of Mountains, how meaſured.—Computed Heights of the moſt remarkable Mountains.—Line of Congelation in different Parts of the World.

ELEVATIONS, conſiſting chiefly of clay, ſand, or gravel, are called hills. Thoſe which conſiſt chiefly of ſtone are called mountains. Mountains are divided into primæval, that is, of equal date with the formation of the globe, and ſecondary or alluvial. Among primæval, thoſe of granite hold the firſt place. The higheſt mountains and moſt extenſive ridges throughout the globe are of that kind; as the Alps and Pyrennees, in Europe; the Altuiſchan, Uralian, and Caucaſus, in Aſia; and the Andes, in America. The higheſt of them never contain metallic ores; but ſome of the lower contain ores of copper and tin. The granite next the ore always abounds in mica. Petrifactions are never found in theſe primæval mountains.

That the formation of theſe mountains preceded that of vegetables and animals, is juſtly inferred from their containing no organic remains, either in the form of petrifaction or impreſſion. Naturaliſts are agreed, that granites were formed by cryſtallization. This operation probably took place after the formation of the atmoſphere, and the gradual excavation of the bed of the ocean, when the dry land appeared. For, as was remarked in the preceding chapter, by means of the ſeparation of the aeriform fluids, which conſtitute the atmoſphere, the evaporation of part of the water into the atmoſphere, and the gradual retreat of the remainder, the various ſpecies of earths, before diſſolved or diffuſed through this mighty maſs, were diſpoſed to coaleſce, and among theſe the ſiliceous muſt have been the firſt, as it is the leaſt ſoluble; but as the ſiliceous earth has an affinity to the other earths with which it was mixed, ſome of theſe muſt have united in various proportions, and thus have formed, in diſtinct maſſes, the felt ſpar, ſhoerl, and mica, which compoſe the granite. Calcareous earth enters very ſparingly into the compoſition of this ſtone; but as it is found in ſhoerl, which is frequently a component part of granite, it follows that it muſt be one of the primitive earths, and not entirely derived from marine exuviæ, as ſome have ſuppoſed. Quartz can never be ſuppoſed to be a product of fire; for in a very low heat it burſts, cracks, and loſes its tranſparency, and in the higheſt degree of heat that we can produce, is infuſible, ſo that in every eſſential point it is different from glaſs, to which ſome have compared it. As granite contains earths of every genus, we may conclude, that all the ſimple earths are original. This, however, is no proof that they are in reality ſimple and uncompounded of other principles; but they muſt be conſidered as ſuch in the preſent ſtate of our knowledge. Though water undoubtedly dates from creation, yet late experiments have ſhewn it to be a compound, as was formerly ſtated.

Mountains, which conſiſt of lime-ſtone or marbles of a granular or ſcaly texture, and not diſpoſed in ſtrata, ſeem alſo to have preceded the creation of animals, for no organic traces are found in them. Some of thoſe, which conſiſt of argillaceous ſtones, and ſome of the ſiliceous, contain alſo no organic remains. Theſe often conſiſt of parallel ſtrata of unequal thickneſs, and the lower are harder and leſs thick than the upper, and therefore ſeem to have been formed earlier than the upper.

Alluvial mountains are evidently of poſterior formation, as they contain petrifactions and other veſtiges of organic ſubſtances, and theſe are always ſtratified.

Mountains, as to ſtructure, are entire, ſtratified, and confuſed. Entire mountains are formed of huge maſſes of ſtone, without any regular fiſſures, and are moſtly homogeneous. They conſiſt chiefly of granite, ſometimes gneiſs *, ſchiſtus, flag-ſtone, ſand-ſtone, lime-ſtone, gypſum, porphyry or trapp. Some in Sweden and Norway conſiſt of iron ore.

The ſtratified mountains are thoſe whoſe maſs is regularly divided by joints or fiſſures; theſe are called horizontal, riſing, or dipping. Homogenous ſtratified

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* A rock conſiſting of mica, lapis ollaris, and quartz.

tified mountains conſiſt chiefly of ſtones of the argillaceous genus, or of the fiſſile compound ſpecies of the ſiliceous genus, as metallic rock; ſometimes of lime-ſtone of a granular or ſcaly texture, in which no animal veſtiges appear. This lime-ſtone repoſes on the argillaceous or ſiliceous ſtrata: ſometimes the argillaceous are covered with maſſes of granite, ſometimes of lava. Theſe mountains, particularly thoſe of gneiſs, metallic rock, and horn-ſtone, are the chief ſeat of metallic ores. When covered with lime-ſtone, the ore is generally between the lime-ſtone and the argillaceous ſtones. Theſe ores run in veins, not in ſtrata. Petrifactions are found upon, but not in, theſe mountains.

Heterogeneous, or compound ſtratified mountains, conſiſt of alternate ſtrata of various ſpecies of ſtones, earths, ſands, &c. The lime-ſtone here is always of the laminar, and not of the granular or ſcaly kind, and when it contains any ore, it is placed between its laminæ. Stones of the ſiliceous genus ſeldom form ſtrata in theſe mountains, except lavas; but the ſtrata are frequently interrupted by ſiliceous maſſes, as jaſper, porphyry, &c. Coal, bitumen, petrifactions, and organic impreſſions, are found in theſe mountains, alſo ſalts and calamine.

There are other mountains, which cannot properly be called ſtratified, as they conſiſt only of three immenſe maſſes, the loweſt granite, the middle argillaceous, and the upper lime-ſtone. Metallic ores are found in the argillaceous part, or between it and the lime-ſtone.

Confuſed mountains conſiſt of ſtones heaped together without order, their interſtices filled with clay, ſand, and mica. They ſcarcely ever contain any ore.

Beſides theſe, there are many mountains in different parts of the world, which derive their origin from volcanoes; but of theſe it will be neceſſary to treat in the ſucceeding chapter.

The height of mountains is uſually calculated by means of the barometer, upon the principles already explained. For this purpoſe two columns of mercury, or barometers, are provided, and one is kept at the foot of the mountain while the other is carried to its ſummit. The degree of heat, if not equal, is reduced by calculation to an equality, and for this purpoſe a thermometer is attached to each of the barometers. The degree of heat, to which both are reduced, is commonly 55°. If, however, either of the barometers ſtands at thirty inches, and the annexed thermometer at 55°, no reduction is to be made in the degrees indicated by that barometer; but if either of them is at 30°, and the thermometer below 55°, we muſt add the expanſion the mercury in the barometer would have experienced at the heat of 55°. If the heat ſhould, on the contrary, be above 55°, we muſt ſubſtract the degree of expanſion which it gains by that heat. Every degree of Farenheit's ſcale produces an expanſion of 00.304 of the barometrical inch, when the barometer is at 30; when, therefore, the thermometer is at 11° below or above 55°, we muſt add in the former, or ſubſtract in the latter caſe, eleven times that number from the barometrical height. In the ſame manner it may be calculated, whatever is the height of the barometer. When this matter is aſcertained, the height is eaſily found by comparing the two barometers, and calculating the denſity of the air in the higher regions according to the principles of geometrical progreſſion.

The higheſt mountains are thoſe which are ſituated at or near the equator; and the Andes are generally allowed to be the higheſt of theſe. Catopaxi, one of the Andes, which was meaſured by Ulloa and the French academicians, was found to be rather more than three miles above the level of the ſea; whereas the higheſt point of the Alps is not above a mile and a half. Mount Caucaſus approaches neareſt to the height of the Andes of any of the Aſiatic mountains. The Pike of Teneriff, which has been ſo much celebrated, is about a mile and a half in height. It is an extraordinary circumſtance, that the moon, which is a body ſo much ſmaller than our earth, ſhould ſo greatly exceed it in the irregularities of its ſurface; ſome of the mountains in that planet being calculated to exceed nine miles in height.

The line of congelation, or perpetual froſt, on mountains, is calculated at 15,400 feet, at or near the equator; at the entrance of the temperate zone, at 13,428; on Teneriffe, at 1,000; in Auvergne (lat. 45.) 6,740; with us (lat. 52.) 5,740. On the Andes, vegetation ceaſes at 14,697 feet; and on the Alps, at 9,585. The air is ſo dry in theſe elevated ſituations, that M. D'Arcel obſerved, that on the Pic de Midi, one of the Pyrenees, ſalt of tartar remained dry for an hour and a half, though it immediately moiſtened in the ſame temperature at the bottom of the mountain.

CHAP. XLV.

VOLCANOES.

General Obſervations on Volcanoes.—Their Connection with the Sea. —Immenſe Force of ſubterraneous Fires exemplified in various Inſtances.—Theory of Volcanoes.—Great Depth.—Traces of Volcanoes in different Parts of the World.—Deſcription of Ætna.— Eruption of Veſuvius, in 1794.

VOLCANOES are peculiar to no climate, and have no neceſſary or regular connection with any other mountains, but ſeem to have ſome with the ſea, for they are generally in its neighbourhood. It has been remarked by thoſe who have obſerved them, that volcanoes often throw out matters which belong to the ſea, as the relics of fiſh, ſea-weed, and often immenſe quantities of ſea-water itſelf. Sir William Hamilton obſerves, in the Philoſophical Tranſactions for the year 1776, "that the operations of Veſuvius are very capricious and uncertain, except that the ſmoke increaſes conſiderably and conſtantly when the ſea is agitated, and the wind blows from that quarter."

There are ancient extinguiſhed volcanoes, it is true, which are inland; but this is only one of many proofs that the ſea covered thoſe countries at ſome remote period. Volcanic mountains are of all heights; ſome ſo low as four hundred and fifty feet, as that of Tanna; Veſuvius is three thouſand ſix hundred feet high, and Ætna eleven thouſand.

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They in general form lofty ſpires, and the volcano itſelf is internally ſhaped like an inverted cone, placed on a broader baſis. This cone is called the crater, or bowl, and through it the lava generally paſſes, though ſometimes it burſts through the ſides, and even proceeds occaſionally from the bottom of the mountain. Sometimes the crater falls in and is effaced, ſometimes, in extinguiſhed volcanoes, it is filled with water. Sub-marine volcanoes have been obſerved, and from theſe ſome iſlands have derived their origin. Volcanic fires, taking place at the bottom of the ocean, would frequently, by the expanſive force of the ſteams which are generated, elevate thoſe parts which were once at the bottom of the deep, and overflow thoſe which were habitable earth. It is very probably conjectured, as was noticed in a preceding chapter, that ſubterraneous convulſions operated more powerfully in the early ages of the world than at any later period; and indeed ſuch an hypotheſis is ſupported by the moſt probable reaſoning, ſince we may well conceive, that at the firſt conſolidation of the earth, much heterogeneous matter would be included in the different maſſes, which might produce more frequent fermentations than at any after periods, when theſe have been, if I may ſo expreſs it, purged off by frequent eruptions, and in many parts, perhaps, rectified and aſſimilated by ſlow and ſecret proceſſes in the bowels of the earth. But hiſtory was not cultivated till a very late period, and the moſt eventful ages of nature have paſſed unrecorded.

The force of ſubterraneous fires, or rather of the ſteam which is generated by them, is ſo great, that conſiderable rocks have been projected by Veſuvius to the diſtance of eight miles. A ſtone was once thrown from the crater of that volcano twelve miles, and fell upon the Marquis of Lauro's houſe at Nola, to which it ſet fire. One alſo, which meaſured twelve feet in height and forty-five in circumference, was carried, in 1767, by the projectile force of the ſteam, a quarter of a mile from the crater. In an eruption of Ætna, a ſtone, fifteen feet long, was ejected from the crater to the diſtance of a mile, and buried itſelf eight feet deep in the ground.

A volcano broke forth in Peru, in 1600, accompanied with an earthquake, and the ſand and aſhes which were ejected covered the fields ninety miles one way and one hundred and twenty another. Dreadful thunders and lightning were heard and ſeen for upwards of ninety miles round Araquapa during this eruption, which ſeemed to denote ſome connection between the electric matter and theſe volcanic fires *; and this fact is ſtrongly confirmed by the very accurate obſervations of Sir William Hamilton, which I ſhall afterwards have occaſion to notice more at large.

Both the inſide of the crater and the baſis of many volcanoes conſiſt of lava, either entire or decompoſed, nearly as low as the level of the ſea, but they finally reſt either on granite, as in Peru, or ſchiſtus, as the extinguiſhed volcanoes of Heſſe and Bohemia, or on lime-ſtone, as thoſe of Sileſia,

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* Dr. Hooke's poſthumous Works, p. 304.

Mount Veſuvius, &c. No ore is found in theſe mountains, except that of iron, of which lava contains from twenty to twenty-five parts in the hundred, and ſome detached fragments of the ores of copper, antimony, and arſenic. Veſuvius ejected, from the year 1779 to 1783, 309,658,161 cubic feet of matter of different kinds; we muſt therefore conclude the ſeat of theſe fires to be ſeveral miles, perhaps hundreds of miles, below the level of the ſea; and as iron makes from one-fourth to one-fifth of theſe ejections, we may infer that the internal parts of the earth abound much in this metal.

The origin of theſe ſubterraneous fires is not eaſily explained. Iron filings mixed with powdered ſulphur, and the whole moiſtened with water into a paſte, we have formerly ſeen, will ſwell, become hot, and, if the quantity is conſiderable, will throw out a blue flame. It is a mixture of this kind which is uſed for making an artificial earthquake, for ſuch a quantity of inflammable gas is produced during the fermentation, that if the maſs is buried in the earth, the gas will force a paſſage for its eſcape, and exhibit, on a ſmall ſcale, the phenomena of an earthquake. M. Lemery ſeems to have been the firſt perſon who illuſtrated, in this manner, the origin of volcanic fires and earthquakes. He mixed twenty-five pounds of iron filings with an equal weight of ſulphur, and having made them into a paſte with the addition of water, he put them into a pot, covered them with a cloth, and buried them a foot under ground. In about eight or nine hours time the earth ſwelled, became warm, and cracked, and hot ſulphureous vapours were perceived*. Now, large beds of martial pyrites, which are natural combinations of iron and ſulphur, are known to exiſt in different parts of the earth; the only difficulty which attends this explanation of the origin of volcanoes, as well as of earthquakes, is, that the preſence of air is in general neceſſary for the production of actual flame. It is well known, however, that martial pyrites, when moiſtened, acquire heat; and if we ſuppoſe the heated pyrites to have been in contact with black wad and petroleum, we may ſuppoſe the flame to ariſe, as we ſee it produced by art, from the deſiccation of the former ſubſtance, and its mixture with mineral oil. Many minerals, when heated, afford vital air, a very ſmall quantity of which is ſufficient to produce flame; this flame, once produced, may be ſupported from other ores, and the combuſtion be maintained by the preſence of bituminous ſchiſtus, bitumen, and coal. Marl, ſchiſtus, horn-ſtone, ſhoerl, with a further addition of iron, are the true ſources of lava. It ſeems, however, after all, difficult to conceive that ſuch extenſive and intenſe fires ſhould be maintained without the acceſs of conſiderable quantities of air; that ſubſtance may therefore be poſſibly ſupplied by a communication with ſome extenſive caverns, which may themſelves receive it by openings at the diſtance of many miles from the crater of the volcano. It does not ſeem improbable that the volcanoes, which now burn, may have a communication with the cavities and craters of extinguiſhed volcanoes, and thence derive a ſupply of air ſufficient to account for the inflammation of large beds of pyrites and bituminous matters. M. Buffon ſuppoſes, that the ſeat of volcanic fires is ſituated but a very little way below the bed of the mountains; but it appears more probable, that it is in general many miles below the ſurface of the earth, for the quantity of matter diſcharged from Ætna alone is ſuppoſed, on a moderate calculation, to exceed twenty times the original bulk of the mountain, and therefore could not have been derived from it contents alone, but alſo from the deeper receſſes of the earth.

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* That part of this experiment (ſays Biſhop Watſon) which relates to the production of fire, by the fermentation of iron filings and ſulphur when made into a paſte, has been frequently repeated ſince the time of Mr. Lemery. I myſelf have made it more than once, but I have nothing material to add to his account, except that the flame, when the experiment is made in the open air, is of very ſhort duration; and that the whole maſs, after the extinction of the flame, continues at intervals, for a longer or ſhorter time, according to its quantity, to throw out ſparks; and that a ladle full of the ignited maſs, being dropped down from a conſiderable height, deſcends like a ſhower of red-hot aſhes, much reſembling the paintings of the eruptions of Mount Veſuvius, which may be ſeen at the Britiſh Muſeum. It has been obſerved, that large quantities of the materials are not requiſite to make the experiment ſucceed, provided there be a due proportion of water: half a pound of ſteel filings, half a pound of flowers of brimſtone, and fourteen ounces of water, will, when well mixed, acquire heat enough to make the maſs take fire.

That heat and fire ſhould be generated from the ſpontaneous actions of *minerals* upon each other, is a phenomenon by no means ſingular in nature, how difficult ſoever it may be to account for it. The heat of putreſcent dunghills, of the fermenting juices of vegetables, and, above all, the ſpontaneous firing of hay not properly dried, are obvious proofs that *vegetables* poſſeſs this property as well as minerals. In both vegetables and minerals, a definite quantity of moiſture is requiſite to enable them to commence that inteſtine motion of their parts, which is neceſſary for the production of fire. Iron and ſulphur would remain mixed together for ages without taking fire, if they were either kept perfectly free from moiſture, or drenched with too much water; and vegetables in like manner, which are quite dry, or exceedingly wet, are incapable of taking fire whilſt they continue in that ſtate.

M. Condamine aſſerts, that all the mountains in the neighbourhood of Naples exhibit undoubted marks of a volcanic origin. He ſays, he could trace the lava, and other productions of ſubterraneous fire, from Naples to the very gates of Rome, pervading the whole ſoil, ſometimes pure and ſometimes differently combined. "Wherever I ſee," ſays he, "on an elevated plain, a circular baſon, ſurrounded with calcined rocks, I am not deceived by the verdure of the adjacent fields; I can diſcover, beneath the ſnow itſelf, the traces of an extinguiſhed fire. If there is a breach in the circle, I uſually find out, by following the declivity of the ground, the traces of a rivulet, or the bed of a torrent, which ſeems as if it was hollowed in the rock, and this rock appears frequently to be pure lava. If the circumference of the baſon has no breach, the rain and ſpring waters, which are collected there, generally form a lake in the very mouth of the volcano." The Apennines, as well as the Cordeliers of Peru and Chili, he ſuppoſes to have been a chain of volcanoes. The chain in both inſtances is interrupted, and many of the fires either extinguiſhed or ſmothered, but many remain ſtill actually burning. This intelligent author is, however, far from attributing to all mountains the ſame origin; and adds, that in that part of the Alps, which he travelled over, he could obſerve no ſuch appearances.

The traces of volcanoes have been obſerved in Ireland by Mr. Whitehurſt. Though no viſible crater is remaining between Port Ruſh Strand and Balley Caſtle eaſtward, yet, he obſerves, that whole ſpace, about twenty Engliſh miles, is one continued maſs of lava. The cliffs, he ſays, are truly ſtupendous, and bear every poſſible mark of having been originally liquid fire. The elevation of that, at the foot of which the Giant's Cauſeway is ſituated, he preſumes cannot be leſs than five or ſix hundred feet perpendicular above the level of the Atlantic ocean, and yet compoſed entirely of lava; the ſame appearances extend towards the ſouth upwards of twenty miles.

The moſt remarkable volcanoes in Europe are Ætna and Veſuvius, and as theſe are not too far diſtant, we have the moſt accurate deſcriptions of them from travellers of the firſt talents and reputation.

‘ Ætna, which is the moſt ſtriking object in Sicily, and indeed one of the moſt magnificent productions of nature, ariſes from an immenſe baſe, and mounts equally on all ſides to its ſummit. The aſcent on each ſide is computed at about thirty miles, and the circumference of its baſe, at one hundred and thirty-three; but as it has never been meaſured with any great degree of accuracy, its dimenſions are but imperfectly known.

‘ The whole mountain is divided into three diſtinct regions, called *La Regione Culta*, or *Piedmonteſe*, the fertile regions; *La Regiona Sylvoſa*, or *Nemoroſa*, the woody region; and *La Regiona Deſerta*, or *Scoperta*, the barren region. Theſe differ as materially both in climate and production as the three zones of the earth, and perhaps with equal propriety might have been ſtiled the torrid, the temperate, and the frigid zone.

‘ The firſt region of Ætna ſurrounds the baſe of the mountain, and conſtitutes the moſt fertile country in the world on all ſides of it, to the extent of fourteen or fifteen miles, where the woody region begins. It is compoſed almoſt entirely of lava, which, in time, becomes the moſt fertile of all ſoils, but the roads, which are entirely over old lavas, now converted into orchards, vineyards, and corn-fields, are very execrable. The lavas, which form this region, ariſe from a number of beautiful little mountains, every where ſcattered over the immenſe declivities of Ætna. Theſe are all either of a conical or ſemiſpherical figure, and are in general covered with beautiful trees, and the moſt luxurious verdure. The formation of them is owing to the internal fires of Ætna, which raging for a vent, at ſo vaſt a diſtance from the great crater that it cannot poſſibly be carried to the height of twelve or thirteen thouſand feet, which is probably the height of the ſummit of Ætna, muſt neceſſarily be diſcharged at ſome other orifice. After ſhaking the mountain, and its neighbourhood for ſome time, at length the fire burſts open its ſide, and this is called an eruption. At firſt it emits only a thick a thick ſmoke and ſhowers of aſhes. Theſe are followed by red hot ſtones, and rocks of a great ſize, which are thrown to an immenſe height in the air. Theſe ſtones, together with the quantities of aſhes diſcharged at the ſame time, form thoſe mountains, which cover all the declivities of Ætna. The ſize of them is in proportion to the duration of the eruption. When it continues a conſiderable time, it ſometimes forms an elevation of one thouſand feet in perpendicular height, which at its baſe is ſeven or eight miles in circumference.

'After the formation of the new mountain, the lava commonly burſts out from its lower ſide, and, ſweeping every thing before it, is generally terminated by the ſea. Sometimes it iſſues from the ſide of the mountain, without theſe attending circumſtances, which is commonly the caſe with the eruptions of Veſuvius, in which the elevation being ſo much ſmaller the melted matter is carried up into the crater, where it is diſlodged without forming any new mountain, but only adding to the height of the old one; till at length the lava, riſing near the ſummit, burſts the ſide of the crater. But Ætna being upon a much larger ſcale, one crater is not ſufficient to give vent to ſuch immenſe oceans of liquid fire.

'At Nicoloſi, which is only twelve miles up the mountain, the climate appears totally changed. When the heats at Catania are inſupportable, and the harveſt entirely over, the temperature of the air is moderate at Nicoloſi, and in many places the corn quite green. Mr. Brydone, in travelling over Ætna, was ſtruck with the degree of wildneſs and ferocity which appeared in the inhabitants of the mountain, and which reminded him of an obſervation made by the Padre della Tore, the hiſtoriographer of Mount Veſuvius, that in places where the air is moſt impregnated with ſulphur and hot exhalations, the people are always moſt wicked and vicious. It was with great difficulty he could perſuade the people of Nicoloſi to ſuffer his guide to attend him in the proſecution of his reſearches. They were exceſſively troubleſome, and extremely ſuſpicious that his views were directed to the diſcovery of ſome hidden treaſure, the only motive to which they could aſcribe ſo fatiguing a journey. At length one of them recollected having heard many of their old people ſay, that the Engliſh had a queen that had burnt in the mountain for many years paſt, and imputed the viſits of ſeveral of that nation to their reſpect to their deceaſed ſovereign. Upon enquiring who this queen was, they ſaid her name was Anna, that ſhe was wife to a king who had been a chriſtian, but ſhe had made him a heretic, and was condemned to burn for ever in Mount Ætna. As this could only relate to the unfortunate Anne Bullen, Mr. Brydone aſked if ſhe was the victim alluded to, and whether her huſband was not likewiſe condemned to the ſame puniſhment. "Certainly," ſaid the man, "and all his heretic ſubjects too; and if you are of that number you need not be in ſuch a hurry to get there, you will be ſure of it at laſt."

'The beautiful country of Hybla, in the neighbourhood of Nicoloſi, after repeated viciſſitudes, is now reduced to a melancholy monument of the fury of Ætna; it was ſo much celebrated for its fertility, and particularly for its honey, that it was called Mel Paſſi, till it was overwhelmed by the lava of Ætna, and became totally barren, when, by a kind of pun, it obtained the name of Mal Paſſi. On a ſecond eruption, however, a fertile ſhower of aſhes reſtored its priſtine beauty, and its former appellation. But in the dreadful eruption of 1669 it was again reduced to the moſt deplorable ſterility, ſince which it is once more known by the name which denotes its wretchedneſs. The eruption that firſt deſtroyed this beautiful country, iſſued from Montpelieri, which it then formed. It deſtroyed a great number of villages and palaces, and in particular two noble churches, which are extremely regreted on account of three ſtatues, accounted, at that time, the moſt perfect in the iſland. They have attempted to recover them, but in vain, nor is it believed they ever can; for the churches were built of lava, which is ſuppoſed to melt as ſoon as it comes into contact with a torrent of new erupted matter. Maſſa, a Sicilian author of great credit, affirms, that in ſome eruptions of Ætna, the lava has poured down with ſuch a ſudden impetuoſity, that, in the courſe of a few hours, palaces, churches, and villages, have been entirely melted down, and the whole run off in fuſion. It is however probable, that the impetuous force of the torrent, rather than its incorporating with the old maſs, may in many of theſe inſtances have occaſioned this devaſtation. Thus much at leaſt is certain, that if the lava has had any conſiderable time to cool, this ſingular effect never happens.

The contraſt between the different regions of Ætna is extremely ſtriking. On entering into the romantic foreſts of the Regione Sylvoſa, a new creation ſeems to ariſe. The air, which before was hot and ſultry, is cool and refreſhing, and every breeze loaded with delicious perfumes from the aromatic plants, with which the whole ground is covered. Indeed every beauty, and every horror in nature, ſeems to be united on this wonderful mountain, and the moſt oppoſite and diſſimilar objects are promiſcuouſly blended together. Here we obſerve a gulph which threw out torrents of fire, now covered with the moſt luxurious verdure. Delicious fruits ariſing from what was but lately a black and barren rock. Delightful flowers covering the earth, the ſurface of which is but a few yards removed from lakes of liquid fire and brimſtone. An immenſe gulph of fire for ever exiſting in the midſt of ſnows which it has not the power to melt, and immenſe fields of ſnow and ice unceaſingly ſurrounding this gulph of fire which they have not the power to extinguiſh.

The woody region of Ætna aſcends for about eight or nine miles, and forms a zone of the brighteſt green around the mountain. In this region, near the *Spelonca del Capriole*, or goats cavern, are two of the moſt beautiful mountains that adorn the ſides of Ætna. Their hollow craters are each of them conſiderably larger than that of Veſuvius. They are now filled with ſtately oaks, and covered with the richeſt ſoil to a great depth. A mountain at ſome diſtance which was formed by an eruption in 1766, was, in 1770, ſtill on fire; nor was the lava by any means cold. This region of Ætna, like the *Regione Culta*, is compoſed of lava; but this is now covered with ſo deep a layer of earth, that it is no where to be ſeen, except in the beds of the torrents, in many of which it is worn down by the water to the depth of fifty or ſixty feet, and in one of them conſiderably more. On approaching *La Regione Scoperta*, the trees begin to aſſume a wintry appearance, and every object indicates the proximity of barrenneſs and eternal froſt.

On completely bidding adieu to the vegetable regions, an expanſe of ice preſents itſelf, which is ſufficient to ſtagger the moſt determined reſolution. Above theſe the high ſummit of the mountain rears its tremendous head, vomiting torrents of thick ſmoke. The difficulty of aſcending this part of the mountain is greatly increaſed by the uncertainty of a ſecure footing; for the ſurface of the mountain being hot below, frequently melts the ſnow in particular ſpots, and forms pools of water where it is impoſſible to foreſee the danger; ſometimes, likewiſe, it happens that the ſurface of the water, as well as the ſnow, is covered with black aſhes, which render it exceedingly deceitful. At firſt the aſcent is not ſo ſteep, but it becomes ſo by degrees. In this region are the remains of an ancient ſtructure called *Il Torre del Filoſofo*, and ſuppoſed to have been built by Empedocles, a native of Agrigentum, who is ſaid to have died 400 years before the chriſtian era. His vanity, perhaps, rather than his philoſophy, led him to this elevated ſituation. Deſirous of being regarded as a god, he is recorded to have thrown himſelf into the great gulph of Ætna, in hopes that the people would imagine he had been taken up to heaven, and never ſuppoſing that his death would be diſcovered to mankind. But the treacherous mountain threw out his ſlippers, which were of braſs, and announced to the world the fate of the pretended philoſopher, who preferred an airy fame, which he was beyond the reach of enjoying, to the ſolid advantages of exiſtence, and who was content to purchaſe the admiration of an ignorant multitude with the meanneſs of deceit, and the ſacrifice of life.*

Many ſtriking remains of the great eruption in 1669 are ſtill to be ſeen, and will long continue as memorials of that dreadful event which overwhelmed Catania, and all the adjacent country. Tremendous earthquakes ſhook the iſland, and loud ſubterraneous bellowings were heard in the mountain. During ſome weeks, the ſun ceaſed to appear, and the day ſeemed changed into night. Borelli, who was a witneſs to theſe terrible phenomena, ſays, that at length a rent, twelve miles in length, was opened in the mountain, in ſome places of which, when they threw down ſtones, they could not hear them reach the bottom. Burning rocks, ſixty palms in length, were thrown to the diſtance of a mile, and leſſer ſtones were carried three miles. After the moſt violent ſtruggles, and a ſhaking of the whole iſland, an immenſe torrent of lava guſhed from the rent, and ſprung up into the air to the heighth of ſixty palms, whence it poured down the mountain, overwhelming every object in its way in one promiſcuous ruin.

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* See preſent ſtate of Sicily and Malta.

This deſtructive torrent, which burſt from the ſide of Ætna at a place called Ricini, ruſhed impetuouſly againſt the beautiful mountain of Montpelieri, and pierced into the ground to a conſiderable depth; then dividing and ſurrounding the mountain, it united again on the ſouth ſide, and poured deſolation upon the adjacent country. The progreſs of the torrent was at firſt at the rate of ſeven miles a day, but it afterwards took four days to travel ſixteen; wherever it directed its courſe, the whole appearance of nature was changed, ſeveral hills were formed in places which were formerly valleys, and a large lake was ſo entirely filled up by the melted maſs, as not to leave a veſtige remaining. In its courſe it deſcended upon a vineyard, belonging to a convent of Jeſuits, which was formed upon an ancient and probably a very thin layer of lava, with a number of caverns and crevices under it. The liquid maſs entering into theſe excavations ſoon filled them up, and by degrees bore up the vineyard, which in a ſhort time, to the great aſtoniſhment of the ſpectators, began to move away, and was carried by the torrent to a conſiderable diſtance. In 1770 ſome remains of this vineyard were ſtill to be ſeen, but the greater part of it was entirely deſtroyed.

In vain did the terrified inhabitants of Catania recur for protection to the miraculous veil, or expect defence from the lofty walls of their city. After deſtroying ſeveral convents, churches, and villages, this fiery current directed its courſe to Catania, where it poured impetuouſly over the ramparts, which are near ſixty feet in height, and covered up five of its baſtions, with the intervening curtains. After laying waſte a great part of this beautiful city, and entirely deſtroying ſeveral valuable remains of antiquity, its further progreſs was ſtopped by the ocean, over whoſe banks it poured its deſtructive current. In its courſe from the rent in the mountain, till its arrival in the ſea, it is ſaid to have totally deſtroyed the property of near thirty thouſand perſons.

Still however did the infatuated inhabitants of Catania adhere to the remains of their almoſt ruined city, nor did even the more dreadful calamity with which they were afterwards viſited, abate their attachment. Twenty-four years after the fatal eruption of 1669, a violent earthquake, which extended along all the eaſtern coaſt, and deſtroyed in one hour more than ſixty thouſand perſons, overthrew the remaining buildings of Catania, and buried a very conſiderable number of its inhabitants under the ruins of their houſes and churches; but again the place was rebuilt, a new and elegant plan was adopted, and the city is now much handſomer than before. The principal ſtreets are wide, ſtrait, and well paved with lava. The cathedral, which was founded in the year 1094, has ſuffered ſo greatly from earthquakes that a very ſmall part of the original ſtructure remains. The other religious edifices are profuſely ornamented, but in a bad taſte.

But if the united effects of attachment to their native ſoil, of contempt for dangers to which they are habituated, and of confidence in the miraculous veil, have occaſioned the wonderful adherence of the Catanians to this dangerous ſituation from which they have ſo ſeverely ſuffered, it muſt, however, be confeſſed that they have ſometimes derived advantages from the very evils which they have ſo much reaſon to dread. They were always in great want of a port, with which they were furniſhed by one of thoſe capricious changes which nature ſo frequently makes in this ever varying ſpot. A ſtream of lava running into the ſea, formed a mole, which no expence could have furniſhed them with. This advantage, however, proved but temporary; there remained for ſome time a ſafe and commodious harbour, but by a ſubſequent eruption it was entirely filled up and demoliſhed.

The celebrated Biſhop Berkeley has deſcribed an eruption of Mount Veſuvius, of which he was a witneſs in the year 1717, and the reader will find his narrative in the firſt volume of Dr. Goldſmith's Hiſtory of the Earth and Animated Nature, p. 94. But the moſt complete and philoſophical account of this moſt formidable phenomenon, a volcanic exploſion, is that with which Sir William Hamilton has favoured the public, in deſcribing the late dreadful eruption of that mountain in 1794; and this I ſhall endeavour to give, as nearly as poſſible, in his own words.

Sir William begins his narrative with remarking, that the frequent ſlight eruptions of lava for ſome years paſt had iſſued from near the ſummit, and ran in ſmall channels in different directions down the flanks of the mountain, and from running in covered channels, had often an appearance as if they came immediately out of the ſides of Veſuvius, but ſuch lavas had not ſufficient force to reach the cultivated parts at the foot of the mountain. In the year 1779, the whole quantity of the lava in fuſion having been at once thrown up with violence out of the crater of Veſuvius, and a great part of it falling, and cooling on its cone, added much to the ſolidity of the walls of this huge natural chimney, and had not of late years allowed of a ſufficient diſcharge of lava to calm that fermentation, which by the ſubterraneous noiſes heard at times, and by the exploſions of ſcoriæ and aſhes, was known to exiſt within the bowels of the volcano; ſo that the eruptions of late years, before this laſt, were ſimply from the lava having boiled over the crater, the ſides being ſufficiently ſtrong to confine it, and oblige it to riſe and overflow. The mountain had been remarkably quiet for ſeven months before the late eruption, nor did the uſual ſmoke iſſue from its crater, but at times it emitted ſmall clouds of ſmoke that floated in the air in the ſhape of little trees. It was remarked by the Father Antonio di Petrizzi, a capuchin friar (who printed an account of the late eruption) from his convent cloſe to the unfortunate town of Torre del Greco, that for ſome days preceding this eruption a thick vapour was ſeen to ſurround the mountain, about a quarter of a mile beneath its crater, as it was remarked by him, and others at the ſame time, that both the ſun and the moon had often an unuſual reddiſh caſt.

The water of the great fountain at Torre del Greco began to decreaſe ſome days before the eruption, ſo that the wheels of a corn-mill, worked by that water, moved very ſlowly; it was neceſſary in all the other wells of the town and its neighbourhood to lengthen the ropes daily, in order to reach at the water; and ſome of the wells became quite dry. Although moſt of the inhabitants were ſenſible of this phenomenon, not one of them ſeems to have ſuſpected the true cauſe of it. Eight days alſo before the eruption, a man and two boys, being in a vineyard above Torre del Greco (and preciſely on the ſpot where one of the new mouths opened, whence the principal current of lava that deſtroyed the town iſſued) were much alarmed by a ſudden puff of ſmoke which iſſued from the earth cloſe to them, and was attended with a ſlight exploſion.

Had this circumſtance, with that of the ſubterraneous noiſes heard at Reſina for two days before the eruption (with the additional one of the decreaſe of water in the wells) been communicated at the time, it would have required no great foreſight to have been certain that an eruption of the volcano was near as hand, and that its force was directed particularly towards that part of the mountain.

On the 12th of June 1794, in the morning, there was a violent fall of rain, and ſoon after the inhabitants of Reſina, ſituate directly over the ancient town of Herculaneum, were ſenſible of a rumbling ſubterraneous noiſe, which was not heard at Naples.

From the month of January to the month of May, the atmoſphere was generally calm, and there was continued dry weather. In the month of May there was a little rain, but the weather was unuſually ſultry. For ſome days preceding the eruption, the Duke della Torre, a learned and ingenious nobleman, who publiſhed two letters upon the ſubject of the eruption, obſerved by his electrometers, that the atmoſphere was charged in exceſs with the electric fluid, and continued ſo for ſeveral days during the eruption.

About eleven o'clock on the night of the 12th of June, the inhabitants of Naples were all ſenſible of a violent ſhock of an earthquake; the undulatory motion was evidently from eaſt to weſt, and appeared to have laſted near half a minute. The ſky, which had been quite clear, was ſoon after covered with black clouds. The inhabitants of the towns and villages, which are very numerous at the foot of Veſuvius, felt this earthquake ſtill more ſenſibly, and ſay, that the ſhock at firſt was from the bottom upwards, after which followed the undulation from eaſt to weſt. This earthquake extended all over the Campagna Felice; and the royal palace at Caſerta, which is fifteen miles from Naples, and one of the moſt magnificent and ſolid buildings in Europe (the walls being eighteen feet thick) was ſhook in ſuch a manner as to cauſe great alarm, and all the chamber bells rang. It was likewiſe much felt at Beneventum, about thirty miles from Naples; and at Ariano in Puglia, which is at a much greater diſtance; both theſe towns, indeed, have been often afflicted with earthquakes.

On Sunday the 15th of June, ſoon after ten o'clock at night, another ſhock of an earthquake was felt at Naples, but did not appear to be quite ſo violent as that of the 12th, nor did it laſt ſo long; at the ſame moment a fountain of bright fire, attended with a very black ſmoke and a loud report, was ſeen to iſſue, and riſe to a great height, from about the middle of the cone of Veſuvius; ſoon after another of the ſame kind broke out at ſome little diſtance lower down; then, as is ſuppoſed by the blowing up of a covered channel full of red hot lava, it had the appearance as if the lava had taken its courſe directly up the ſteep cone of the volcano. Freſh fountains ſucceeded one another haſtily, and all in a direct line tending, for about a mile and a half down, towards the towns of Reſina and Torre del Greco. Sir William Hamilton could count fifteen of them, but believes there were others obſcured by the ſmoke. It ſeems probable, that all theſe fountains of fire, from their being in ſuch an exact line, proceeded from one and the ſame long fiſſure down the flanks of the mountain, and that the lava and other volcanic matter forced its way out of the wideſt parts of the crack, and formed there the little mountains and craters that will be deſcribed in their proper place. It is impoſſible that any deſcription can give an idea of this fiery ſcene, or of the horrid noiſes that attended this great operation of nature. It was a mixture of the loudeſt thunder, with inceſſant reports, like thoſe from a numerous heavy artillery, accompanied by a continued hollow murmur, like that of the roaring of the ocean during a violent ſtorm; and, added to theſe was another blowing noiſe, like that of the aſcending of a large flight of ſky-rockets, or that which is produced by the action of the enormous bellows on the furnace of the Carron iron foundery in Scotland. The frequent falling of the huge ſtones and ſcoriæ, which were thrown up to an incredible height from ſome of the new mouths, and one of which having been ſince meaſured by the Abbé Tata was ten feet high, and thirty-five in circumference, contributed undoubtedly to the concuſſion of the earth and air, which kept all the houſes at Naples for ſeveral hours in a conſtant tremor, every door and window ſhaking and rattling inceſſantly, and the bells ringing. This was an awful moment! The ſky, from a bright full moon and ſtar-light, began to be obſcured; the moon had preſently the appearance of being in an eclipſe, and ſoon after was totally loſt in obſcurity. The murmur of the prayers and lamentations of a numerous populace forming various proceſſions, and parading in the ſtreets, added to the horror. As the lava did not appear to have yet a ſufficient vent, and it was now evident that the earthquakes already felt had been occaſioned by the air and fiery matter confined within the bowels of the mountain, and probably at no ſmall depth (conſidering the extent of thoſe earthquakes) Sir William recommended to the company that was with him, who began to be much alarmed, rather to go and view the mountain at ſome greater diſtance, and in the open air, than to remain in the houſe, which was on the ſea-ſide, and in the part of Naples that is neareſt and moſt expoſed to Veſuvius. They accordingly proceeded to Poſilipo, and viewed the conflagration, now become ſtill more conſiderable, from the ſea-ſide under that mountain; but whether from the eruption having increaſed, or from the loud reports of the volcanic exploſions being repeated by the mountain behind them, the noiſe was much louder, and more alarming than that they had heard in their firſt poſition, at leaſt a mile nearer to Veſuvius. After ſome time, and which was about two o'clock in the morning of the 16th, having obſerved that the lavas ran in abundance, freely, and with great velocity, having made a conſiderable progreſs towards Reſina, the town which it firſt threatened, and that the fiery vapours which had been confined had now free vent through many parts of a crack of more than a mile and a half in length, as was evident from the quantity of inflamed matter and black ſmoke, which continued to iſſue from the new mouths above mentioned, without any interruption, our author concluded that at Naples all danger from earthquakes, which had been his greateſt apprehenſion, was totally removed, and he returned to his former ſtation at St. Lucia at Naples.

All this time there was not the ſmalleſt appearance of fire or ſmoke from the crater on the ſummit of Veſuvius; but the black ſmoke and aſhes iſſuing continually from ſo many new mouths, or craters, formed an enormous and denſe body of clouds over the whole mountain, and which began to give ſigns of being replete with the electric fluid, by exhibiting flaſhes of that ſort of zig-zag lightning, which in the volcanic language of the country is called *ferilli*, and which is the conſtant attendant on the moſt violent eruptions.

Sir William Hamilton proceeds to remark, that during thirty years that he had reſided at Naples, and in which ſpace of time he had been witneſs to many eruptions of Veſuvius, of one ſort or other, he never ſaw the cloud of ſmoke replete with the electric fire, except in the two great eruptions of 1767, that of 1779, and during this more formidable one. The electric fire, in the year 1779, that played conſtantly within the enormous black cloud over the crater of Veſuvius, and ſeldom quitted it, was exactly ſimilar to that which is produced, on a very ſmall ſcale, by the conductor of an electrical machine communicating with an inſulated plate of glaſs, thinly ſpread over with metallic filings, &c. when the electric matter continues to play over it in zig-zag lines without quitting it. He was not ſenſible of any noiſe attending that operation in 1779; whereas the diſcharge of the electrical matter from the volcanic clouds during this eruption, and particularly the ſecond and third days, cauſed exploſions like thoſe of the loudeſt thunder; and indeed the ſtorms raiſed evidently by the ſole power of the volcano, reſembled in every reſpect all other thunder-ſtorms; the lightning falling and deſtroying every thing in its courſe. The houſe of the Marquis of Berio at St. Jorio, ſituate at the foot of Veſuvius, during one of theſe volcanic ſtorms was ſtruck with lightning, which having ſhattered many doors and windows, and damaged the furniture, left for ſome time a ſtrong ſmell of ſulphur in the rooms it paſſed through. Out of theſe gigantic and volcanic clouds, beſides the lightning, both during this eruption and that of 1779, the author adds, he had, with many others, ſeen balls of fire iſſue, and ſome of a conſiderable magnitude, which burſting in the air, produced nearly the ſame effect as that from the air balloons in fire-works, the electric fire that came out having the appearance of the ſerpents with which thoſe fire-work balloons are often filled. The day on which Naples was in the greateſt danger from the volcanic clouds, two ſmall balls of fire, joined together by a ſmall link like a chain-ſhot, fell cloſe to his Caſino at Poſilipo; they ſeparated, and one fell in the vineyard above the houſe, and the other in the ſea, ſo cloſe to it that he heard the ſplaſh in the water. The Abbé Tata, in his printed account of this eruption, mentions an enormous ball of this kind which flew out of the crater of Veſuvius while he was ſtanding on the edge of it, and which burſt in the air at ſome diſtance from the mountain, ſoon after which he heard a noiſe like the fall of a number of ſtones, or of a heavy ſhower of hail. During the eruption of the 15th at night, few of the Inhabitants of Naples, from the dread of earthquakes, ventured to go to their beds. The common people were either employed in devout proceſſions in the ſtreets, or were ſleeping on the quays and open places; the nobility and gentry, having cauſed their horſes to be taken from their carriages, ſlept in them in the ſquares and open places, or on the high roads juſt out of the town. For ſeveral days, while the volcanic ſtorms of thunder and lightning laſted, the inhabitants at the foot of the volcano, both on the ſea ſide and the Somma ſide, were often ſenſible of a tremor in the earth, as well as of the concuſſions in the air, but at Naples only the earthquakes of the 12th and 15th of June were diſtinctly and univerſally felt: this fair city could not certainly have reſiſted, had not thoſe earthquakes been fortunately of a ſhort duration. Throughout this eruption, which continued in force about ten days, the fever of the mountain, as has been remarked in former eruptions, ſhowed itſelf to be in ſome meaſure periodical, and generally was moſt violent at the break of day, at noon, and at midnight.

About four o'clock in the morning of the 16th, the crater of Veſuvius began to ſhow ſigns of being open, by ſome black ſmoke iſſuing out of it; and at day-break another ſmoke, tinged with red, iſſuing from an opening near the crater, but on the other ſide of the mountain, and facing the town of Ottaiano, ſhewed that a new mouth had opened there from which a conſiderable ſtream of lava iſſued, and ran with great velocity through a wood, which it burnt; and having run about three miles in a few hours it ſtopped before it had arrived at the vineyards and cultivated lands. The crater, and all the conical part of Veſuvius, was ſoon involved in clouds and darkneſs, and ſo it remained for ſeveral days; but above theſe clouds, although of a great height, freſh columns of ſmoke were ſeen from the crater, riſing furiouſly ſtill higher, until the whole maſs remained in the uſual form of a pine-tree; and in that gigantic maſs of heavy clouds the ferilli, or volcanic lightning, was frequently viſible, even in the day time. About five o'clock in the morning of the 16th, the lava which had firſt broken out from the ſeveral new mouths on the ſouth ſide of the mountain, had reached the ſea, and was running into it, having overwhelmed, burnt, and deſtroyed the greateſt part of Torre del Greco, the principal ſtream of lava having taken its courſe through the very center of the town (ſee plate II.) *. They obſerved from Naples, that when the lava was in the vineyards in its way to the town, there iſſued often, and in different parts of it, a bright pale flame, and very different from the deep red of the lava; this was occaſioned by the burning of the trees that

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* This view was taken from a boat on the ſea near that town, about five in the morning of the 16th of June, and while the lava was ſtill advancing in the ſea. The rocks, on which are two figures near the boat, were formed by a lava that ran into the ſea during a former eruption of Mount Veſuvius.

ſupported

Vol. II. p. 384. Plate 2.

ſupported the vines. Soon after the beginning of this eruption, aſhes fell thick at the foot of the mountain, all the way from Portici to the Torre del Greco; and what is remarkable, although there were not at that time any clouds in the air, except thoſe of ſmoke from the mountain, the aſhes were wet, and accompanied with large drops of water, which were to the taſte very ſalt; the road, which is paved, was as wet as if there had been a heavy ſhower of rain. Thoſe aſhes were black and coarſe, like the ſand of the ſea-ſhore, whereas thoſe that fell there, and at Naples ſome days after, were of a light-grey colour, and as fine as Spaniſh ſnuff, or powdered bark. They contained many ſaline particles; thoſe aſhes that lay on the ground, expoſed to the burning ſun, had a coat of the whiteſt powder on their ſurface, which to the taſte was extremely ſalt and pungent. In the printed account of the eruption by Emanuel Scotti, doctor of phyſic and profeſſor of philoſophy in the univerſity of Naples, he ſuppoſes (which appears to be highly probable) that the water which accompanied the fall of the aſhes at the beginning of the eruption, was produced by the mixture of the inflammable and dephlogiſticated air.

By the time that the lava had reached the ſea, between five and ſix o'clock in the morning of the 16th, Veſuvius was ſo completely involved in darkneſs, that the violent operation of nature that was going on there could no longer be diſcerned, and ſo it remained for ſeveral days; but the dreadful noiſe, and the red tinge on the clouds over the top of the mountain, were evident ſigns of the activity of the fire underneath. The lava ran but ſlowly at Torre del Greco after it had reached the ſea; and on the 17th of June in the morning, its courſe was ſtopped, excepting that at times a little rivulet of liquid fire iſſued from under the ſmoaking ſcoriæ into the ſea, and cauſed a hiſſing noiſe, and a white vapour ſmoke; at other times, a quantity of large ſcoriæ were puſhed off the ſurface of the body of the lava into the ſea, diſcovering that it was redhot under that ſurface; and even to the latter end of Auguſt the center of the thickeſt part of the lava that covered the town retained its red heat. The breadth of the lava that ran into the ſea, and formed a new promontory there, after having deſtroyed the greateſt part of the town of Torre del Greco, having been exactly meaſured by the duke della Torre, is of Engliſh feet 1204. Its height above the ſea is twelve feet, and as many feet under water; ſo that its whole height is twenty-four feet; it extends into the ſea 626 feet. The ſea water was boiling as in a cauldron, where it waſhed the foot of this new formed promontory: and although our author was at leaſt a hundred yards from it, obſerving that the ſea ſmoked near his boat, he put his hand into the water, which was literally ſcalded; and by this time his boatmen obſerved that the pitch from the bottom of the boat was melting faſt, and floating on the ſurface of the ſea, and that the boat began to leak; he therefore retired haſtily from this ſpot, and landed at ſome diſtance from the hot lava. The town of Torre del Greco contained about 18,000 inhabitants, all of whom (except about 15, who from either age or infirmity could not be moved, and were overwhelmed by the lava in their houſes) eſcaped either to Caſtel-a-mare, which was the ancient Stabiæ, or to Naples; but the rapid progreſs of the lava was ſuch, after it had altered its courſe from Reſina, which town it firſt threatened, and had joined a freſh lava that iſſued from one of the new mouths in a vineyard, about a mile from the town, that it ran like a torrent over the town of Torre del Greco, allowing the unfortunate inhabitants ſcarcely time to ſave their lives; their goods and effects were totally abandoned, and indeed ſeveral of the inhabitants, whoſe houſes had been ſurrounded with lava while they remained in them, eſcaped from them, and ſaved their lives the following day, by coming out of the tops of their houſes, and walking over the ſcoriæ on the ſurface of the redhot lava. Five or ſix old nuns were taken out of a convent in this manner, on the 16th of June, and carried over the hot lava; their ſtupidity was ſuch, as not to have been the leaſt alarmed, or ſenſible of their danger: one of upwards of ninety years of age was found actually warming herſelf at a point of redhot lava, which touched the window of her cell, and which ſhe ſaid was very comfortable; and though now apprized of their danger, they were ſtill very unwilling to leave the convent, in which they had been ſhut up almoſt from their infancy, their ideas being as limited as the ſpace they inhabited. Having been deſired to pack up whatever they had that was moſt valuable, they all loaded themſelves with biſcuits and ſweetmeats, and it was but by accident it was diſcovered that they had left a ſum of money behind them, which was recovered for them.

The lava paſſed over the center and beſt part of the town; no part of the cathedral remained above it, except the upper part of a ſquare brick tower, in which were the bells; and it is a curious circumſtance, that thoſe bells, although they were neither cracked nor melted, were deprived of their tone as much as if they had been cracked. When the lava firſt entered the ſea, it threw up the water to a prodigious height; and particularly when two points of lava met and incloſed a pool of water, that water was thrown up with great violence, and a loud report: at this time, as well as the day after alſo, a great many boiled fiſh were ſeen floating on the ſurface of the ſea.

The lava over the cathedral, and in other parts of the town, is ſaid to be upwards of forty feet in thickneſs; the general height of the lava during its whole courſe was about twelve feet, and in ſome parts not leſs than a mile in breadth.

When Sir William Hamilton viſited it on the 17th of June, the tops of the houſes were juſt viſible here and there in ſome parts, and the timbers within ſtill burning cauſed a bright flame to iſſue out of the ſurface; in other parts, the ſulphur and ſalts exhaled in a white ſmoke from the lava, forming a white or yellow cruſt on the ſcoriæ round the ſpots where it iſſued with the greateſt force. He often heard little exploſions, and ſaw that they blew up, like little mines, fragments of the ſcoriæ and aſhes into the air; theſe he ſuppoſes to have been occaſioned either by rarefied air in confined cellars, or, perhaps, by ſmall portions of gunpowder taking fire, as few in that country are without a gun and ſome little portion of gunpowder in their houſes. As the church feaſts there are uſually attended with fireworks and crackers, a firework-maker of the town had a very great quantity of fireworks ready made for an approaching feaſt, and ſome gunpowder, all of which had been ſhut up in his houſe by the lava, a part of which had even entered one of the rooms; yet he actually ſaved all his fireworks and gunpowder ſome days after, by carrying them ſafely over the ſcoriæ of the lava, that was redhot underneath. The heat in the ſtreets of the town, at this time, was ſo great as to raiſe the thermometer to very near one hundred degrees, and cloſe to the hot lava it roſe much higher. Sir William remarked in his way home, that there was a much greater quantity of the petroleum floating on the ſurface of the ſea, and diffuſing a very ſtrong and offenſive ſmell, than was uſual; for at all times in calms, patches of this bituminous oil are to be ſeen floating on the ſurface of the ſea between Portici and Naples, and particularly oppoſite a village called Pietra Bianca. The minute aſhes continued falling at Naples; and the mountain, totally obſcured by them, continued to alarm the inhabitants with repeated loud exploſions.

On Wedneſday June 18, the wind having for a ſhort ſpace of time cleared away the thick cloud from the top of Veſuvius, it was now diſcovered that a great part of its crater, particularly on the weſt ſide oppoſite Naples, had fallen in, which it probably did about four o'clock in the morning of that day, as a violent ſhock of an earthquake was felt at that moment at Reſina, and other parts ſituate at the foot of the volcano. The clouds of ſmoke, mixed with the aſhes, were of ſuch a denſity as to appear to have the greateſt difficulty in forcing their paſſage out of the now widely extended mouth of Veſuvius, which certainly, ſince the top fell in, cannot be much ſhort of two miles in circumference. One cloud heaped on another, and ſucceeding one another inceſſantly, formed in a few hours ſuch a gigantic and elevated column of the darkeſt hue over the mountain, as ſeemed to threaten Naples with immediate deſtruction, having at one time been bent over the city, and appearing to be much too maſſive and ponderous to remain long ſuſpended in the air; it was beſides, replete with the ferilli, or volcanic lightning, which was ſtronger than common lightning, juſt as Pliny the younger deſcribes it in one of his letters to Tacitus, when he ſays *fulgoribus illæ et ſimiles et majores erant**. (See plate III.)

Veſuvius

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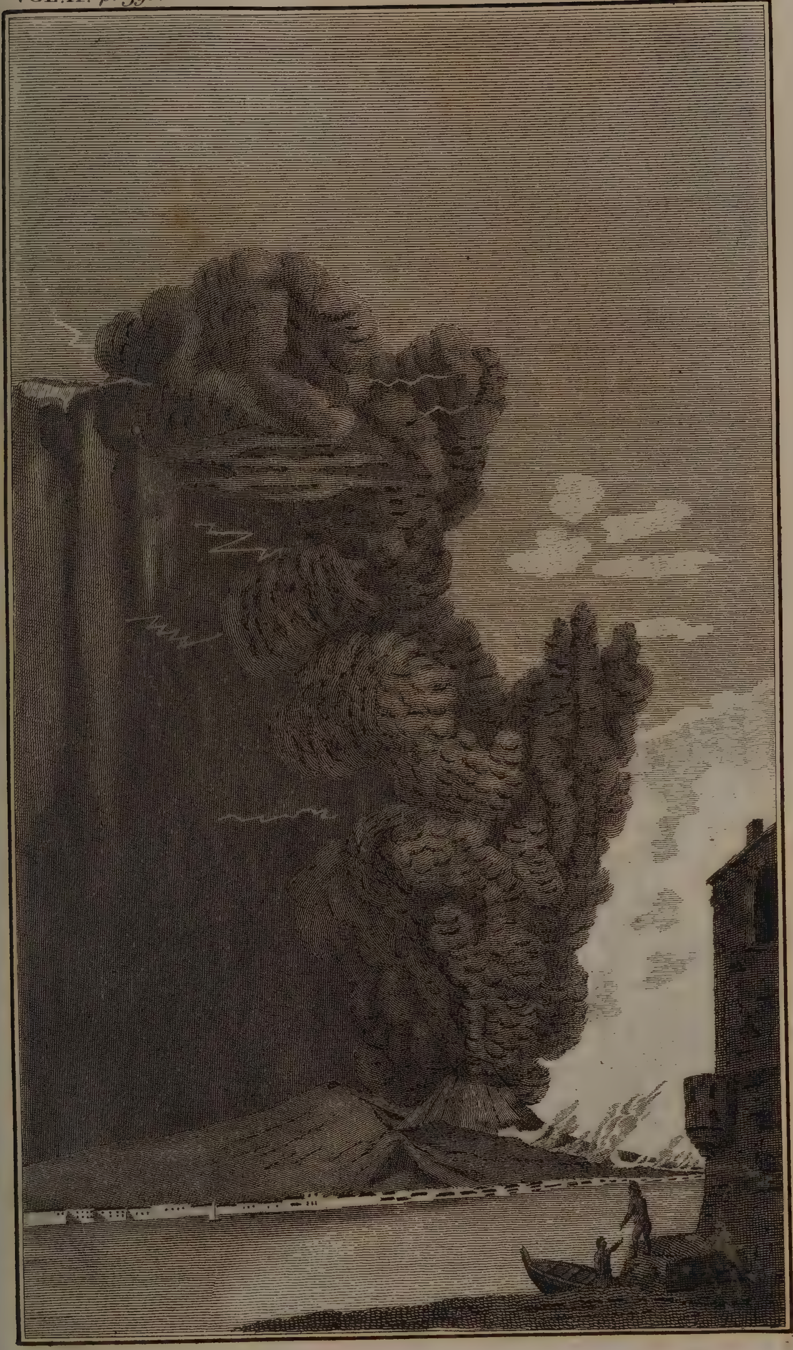
* This view was taken from Naples, and gives a very good idea of the appearance of Mount Veſuvius, like a molehill, in compariſon of the enormous maſs that hung over it.—The black lines ſhow the form of the top of Veſuvius, as it was before this eruption, and when the crater was only the width of the upper line.

Plate 3.



Veſuvius was at this time completely covered, as were all the old black lavas, with a thick coat of thoſe fine light-grey aſhes already fallen, which gave it a cold and horrid appearance; and in compariſon of the abovementioned enormous maſs of clouds, which certainly, however it may contradict our idea of the extenſion of our atmoſphere, roſe many miles above the mountain, it appeared like a molehill, although the perpendicular height of Veſuvius, from the level of the ſea, is more than three thouſand ſix hundred feet. The abbé Braccini, as appears in his printed account of the eruption of Mount Veſuvius in 1631, meaſured with a quadrant the elevation of a maſs of clouds of the ſame nature, that was formed over Veſuvius during that great eruption, and found it to exceed thirty miles in height. Dr. Scotti, in his printed account of this eruption, ſays, that the height of this threatning cloud of ſmoke and aſhes, meaſured from Naples, was found to be of an elevation of thirty degrees.

The ſtorms of thunder and lightning, attended at times with heavy falls of rain and aſhes, cauſing the moſt deſtructive torrents of water and glutinous mud, mixed with huge ſtones, and trees torn up by the roots, continued more or leſs to afflict the inhabitants on both ſides of the volcano until the 7th of July, when the laſt torrent deſtroyed many hundred acres of cultivated land, between the towns

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line. On the ſide of the mountain is repreſented the ſpot whence the lava firſt iſſued on the 15th of June, with its courſe to Torre del Greco and the ſea.

of Torre del Greco and Torre dell' Annunziata. Some of theſe torrents, both on the ſea ſide and the Somma ſide of the mountain, came down with a horrid ruſhing noiſe; and ſome of them, after having forced their way through the narrow gullies of the mountain, roſe to the height of more than twenty feet, and were near half a mile in extent. The mud, of which the torrents were compoſed, being a kind of natural mortar, completely caſed up and ruined ſome thouſand acres of rich vineyards; for it ſoon becomes ſo hard, that nothing leſs than a pickaxe can break it up.

The laudable curioſity of our author induced him to go upon Mount Veſuvius, as ſoon as it was conſiſtent with any degree of prudence, which was not until the 30th of June, and even then it was attended with ſome riſk. The crater of Veſuvius, except at ſhort intervals, had been continually obſcured by the volcanic clouds from the 16th, and was ſo on that day, with frequent flaſhes of lightning playing in thoſe clouds, and attended as uſual with a noiſe like thunder; and the fine aſhes were ſtill falling on Veſuvius, but ſtill more on the mountain of Somma. Sir William went up the uſual way by Reſina, and obſerved, in his way through that village, that many of the ſtones of the pavement had been looſened, and were deranged by the earthquakes, particularly by that of the 18th, which attended the falling in of the crater of the volcano, and which had been ſo violent as to throw many people down, and obliged all the inhabitants of Reſina to quit their houſes haſtily, to which they did not dare return for two days. The leaves of all the vines were burnt by the aſhes that had fallen on them, and many of the vines themſelves were buried under the aſhes, and great branches of the trees that ſupported them had been torn off by their weight. In ſhort, nothing but ruin and deſolation was to be ſeen. The aſhes at the foot of the mountain were about ten or twelve inches thick on the ſurface of the earth, but in proportion as he aſcended, their thickneſs increaſed to ſeveral feet, not leſs than nine or ten in ſome parts; ſo that the ſurface of the old rugged lavas, that before was almoſt impracticable, was now become a perfect plain, over which he walked with the greateſt eaſe. The aſhes were of a light-grey colour, and exceedingly fine, ſo that by the footſteps being marked on them as on ſnow, he learnt that three ſmall parties had been up before him. He ſaw likewiſe the track of a fox, which appeared to have been quite bewildered, to judge from the many turns he had made. Even the traces of lizards and other little animals, and of inſects, were viſible on theſe fine aſhes. Sir William and his companion aſcended to the ſpot whence the lava of the 15th firſt iſſued, and followed the courſe of it, which was ſtill very hot (although covered with ſuch a thick coat of aſhes) quite down to the ſea at Torre del Greco, which is more than five miles. It was not poſſible to get up to the great crater of Veſuvius, nor had any one yet attempted it. The horrid chaſms that exiſted from the ſpot where the late eruption firſt took place, in a ſtrait line for near two miles toward the ſea, cannot be imagined. They formed vallies more than two hundred feet deep, and from half a mile to a mile wide; and where the fountains of fiery matter exiſted during the eruption, were little mountains with deep craters. Ten thouſand men, in as many years, could not make ſuch an alteration on the face of Veſuvius. Except the exhalations of ſulphureous and vitriolic vapours, which broke out from different ſpots of the line abovementioned, and tinged the ſurface of the aſhes and ſcoriæ in thoſe parts with either a deep or pale-yellow, with a reddiſh ochre colour, or a bright white, and in ſome parts with a deep green and azure blue (ſo that the whole together had the effect of an iris) all had the appearance of a ſandy deſart. Our adventurers then went on the top of ſeven of the moſt conſiderable of the new-formed mountains, and looked into their craters, which on ſome of them appeared to be little ſhort of half a mile in circumference; and although the exterior perpendicular height of any of them did not exceed two hundred feet, the depth of their inverted cone within was three times as great. It would not have been poſſible to have breathed on theſe new mountains near their craters, if they had not taken the precaution of tying a doubled handkerchief over their mouths and noſtrils; and even with that precaution they could not reſiſt long, the fumes of the vitriolic acid were ſo exceedingly penetrating, and of ſuch a ſuffocating quality. They found in one a double crater, like two funnels joined together; and in all there was ſome little ſmoke and depoſitions of ſalts and ſulphurs, of the various colours abovementioned, juſt as is commonly ſeen adhering to the inner walls of the principal crater of Veſuvius.

Two or three days after they had been there, one of the new mouths, into which they had looked, ſuddenly made a great exploſion of ſtones, ſmoke, and aſhes, which would certainly have proved fatal to any one who might unfortunately have been there at the time of the exploſion. We read of a like accident having proved fatal to more than twenty people, who had the curioſity to look into the crater of the Monte Nuovo, near Pozzuoli, a few days after its formation, in the year 1538. The 15th of Auguſt, Sir William ſaw a ſudden exploſion of ſmoke and aſhes thrown to an extreme height out of the great crater of Veſuvius, that muſt have deſtroyed any one within half a mile of it; and yet on the 19th of July a party not only had viſited that crater, but had deſcended 170 feet within it. While they were on the mountain, two whirlwinds, exactly like thoſe that form water-ſpouts at ſea, made their appearance; and one of them, which was very near, made a ſtrange ruſhing noiſe, and having taken up a great quantity of the fine aſhes, formed them into an elevated ſpiral column, which, with a whirling motion and great rapidity, was carried toward the mountain of Somma, where it broke and was diſperſed. One of our author's ſervants, employed in collecting of ſulphur, or ſal ammoniac, which cryſtallizes near the fumaroli, as they are called (and which are the ſpots whence the hot vapour iſſues out of the freſh lavas) found, to his great ſurprize, an exceeding cold wind iſſue from a fiſſure very near the hot fumaroli upon his leg. In a vineyard not in the ſame line with the new-formed mountains juſt deſcribed, but in a right line from them, at the diſtance of little more than a mile from Torre del Greco, they found three or four more of theſe new-formed mountains with craters, out of which the lava flowed, and by uniting with the ſtreams that came from the higher mouths, and adding to their heat and fluidity, enabled the whole current to make ſo rapid a progreſs over the unfortunate town, as ſcarcely to allow its inhabitants ſufficient time to eſcape with their lives. The rich vineyards belonging to the Torre del Greco, and which produced the wine called Lacrima Chriſti, that have been buried, and are totally deſtroyed by this lava, conſiſted of more than three thouſand acres; but the deſtruction of the vineyards by the torrents of mud and water, at the foot of the mountain of Somma, was much more extenſive.

In that part of the country, the firſt ſigns of a torrent that our author met with, was near the village of the Madonna dell' Arco, and he paſſed ſeveral others between that and the town of Ottaiano; one near Trochia, and two near the town of Somma, were the moſt conſiderable, and not leſs than a quarter of a mile in breadth; and, according to the teſtimony of eye-witneſſes, when they poured down from the mountain of Somma, they were from twenty to thirty feet high; the matter of theſe torrents was a liquid glutinous mud, compoſed of ſcoriæ, aſhes, ſtones (ſome of an enormous ſize) mixed with trees that had been torn up by the roots. Such torrents, as it may well be imagined, were irreſiſtible, and carried all before them; houſes, walls, trees, and not leſs than four thouſand ſheep and other cattle. At Somma, a team of eight oxen, which were drawing a large timber tree, were at once carried off, and never were heard of more.

The appearance of theſe torrents was like that of all other torrents in mountainous countries, except that what had been mud was become a perfect cement, on which nothing leſs than a pickaxe could make any impreſſion. The vineyards and cultivated lands were here much more ruined; and the limbs of the trees much more torn by the weight of the aſhes, than thoſe which have been already deſcribed on the ſea ſide of the volcano.

The abbé Tata, in his printed account of this eruption, has given a good idea of the abundance, the great weight, and glutinous quality of theſe aſhes, when he ſays, that having taken a branch from a fig-tree ſtill ſtanding near the town of Somma, on which were only ſix leaves, and two little unripe figs, and having weighed it with the aſhes attached to it, he found it to be thirty-one ounces; when having waſhed off the volcanic matter, it ſcarcely weighed three.

In the town of Somma, our author found four churches and about ſeventy houſes without roofs, and full of aſhes. The great damage on that ſide of the mountain, by the fall of the aſhes and the torrents, happened on the 18th, 19th, and 20th of

June, and on the 12th of July. The 19th, the aſhes fell ſo thick at Somma, that unleſs a perſon kept in motion, he was ſoon fixed to the ground by them. This fall of aſhes was accompanied alſo with loud reports, and frequent flaſhes of the volcanic lightning, ſo that, ſurrounded by ſo many horrors, it was impoſſible for the inhabitants to remain in the town, and they all fled; the darkneſs was ſuch, although it was mid-day, that even with the help of torches it was ſcarcely poſſible to keep in the high road. On the 16th of July, ſignor Guiſeppe Sacco went up to the crater, and, according to his account, which has been printed at Naples, the crater is of an irregular oval form, and, as he ſuppoſes (not having been able to meaſure it) of about a mile and a half in circumference; the inſide, as uſual, in the ſhape of an inverted cone, the inner walls of which on the eaſtern ſide are perpendicular; but on the weſtern ſide of the crater, which is much lower, the deſcent was practicable, and Sacco with ſome of his companions actually went down one hundred and ſeventy-ſix palms, from which ſpot, having lowered a cord with a ſtone tied to it, they found the whole depth of the crater to be about five hundred palms. But ſuch obſervations on the crater of Veſuvius are of little conſequence, as both its form and apparent depth are ſubject to great alterations from day to day.

The 22d of July, one of the new craters, which is the neareſt to the town of Torre del Greco, threw up both fire and ſmoke, which circumſtance, added to that of the lava's retaining its heat much longer than uſual, ſeemed to indicate that there was ſtill ſome fermentation under that part of the volcano. The lava in cooling often cracks, and cauſes a loud exploſion, juſt as the ice does in the glaciers in Swiſſerland; ſuch reports were frequently heard at this time at the Torre del Greco; and a vapour was often ſeen to iſſue from the body of the lava, and taking fire in air, fall like thoſe meteors vulgarly called falling ſtars.

The darkneſs occaſioned by the fall of the aſhes in the Campagna Felice extended itſelf, and varied, according to the prevailing winds. On the 19th of June it was ſo dark at Caſerta, which is fifteen miles from Naples, as to oblige the inhabitants to light candles at mid-day; and one day, during the eruption, the darkneſs ſpread over Beneventum, which is thirty miles from Veſuvius.

The archbiſhop of Taranto, in a letter to Naples, and dated from that city the 18th of June, obſerves, 'We are involved in a thick cloud of minute volcanic aſhes, and we imagine that there muſt be a great eruption either of Mount Etna, or of Stromboli.' The biſhop did not dream of their having proceeded from Veſuvius, which is about two hundred and fifty miles from Taranto. Aſhes alſo fell, during the late eruption, at the very extremity of the province of Lecce, which is ſtill farther off; at Martino, near Taranto, a houſe was ſtruck and much damaged by the lightning from one of the clouds. In the accounts of the great eruption of Veſuvius in 1631, mention is made of the extenſive progreſs of the aſhes from Veſuvius, and of the damage done by the ferilli, or volcanic lightning, which attended them in their courſe.

Our author in this place mentions a very extraordinary circumſtance, which happened near Sienna, on the Tuſcan ſtate, about eighteen hours after the commencement of the late eruption of Veſuvius on the 15th of June, although he adds, that phænomenon muſt have no relation to the eruption; it was communicated to him in the following words by the earl of Briſtol, biſhop of Derry, in a letter dated from Sienna, July 12, 1794: ‘ In the midſt of a moſt violent thunder-ſtorm, about a dozen ſtones of various weights and dimenſions fell at the feet of different people, men, women, and children; the ſtones are of a quality not found in any part of the Sienneſe territory; they fell about eighteen hours after the enormous eruption of Veſuvius, which circumſtance leaves a choice of difficulties in the ſolution of this extraordinary phænomenon: either theſe ſtones have been generated in this igneous maſs of clouds, which produced ſuch unuſual thunder, or, which is equally incredible, they were thrown from Veſuvius at a diſtance of at leaſt two hundred and fifty miles; judge then of its parabola.’ One of the largeſt ſtones, when entire, weighed upwards of five pounds. The outſide of every ſtone that was found, and aſcertained to have fallen from the cloud near Sienna, was evidently freſhly vitrified, and black, having every ſign of having paſſed through an extreme heat; when broken, the inſide was found of a light-grey colour mixed with black ſpots, and ſome ſhining particles, ſuppoſed to be pyrites. Stones of the ſame nature, at leaſt as far as the eye can judge of them, are frequently found on Mount Veſuvius; and ſhould ſimilar ſtones be found, with the ſame vitrified coat on them, on Mount Veſuvius, the queſtion would be decided in favour of Veſuvius, unleſs it could be proved that there had been, about the time of the fall of theſe ſtones in the Saneſe territory, ſome nearer opening of the earth, attended with an emiſſion of volcanic matter, which might very well happen, as the mountain of Radicofani, within fifty miles of Sienna, is certainly volcanic. The celebrated father Ambrogio Soldani, profeſſor of mathematics in the univerſity of Sienna, is printing there his diſſertation upon this extraordinary phænomenon; wherein, it is ſaid, he has decided that thoſe ſtones were generated in the air independently of volcanic aſſiſtance.

Until after the 7th of July, when the laſt cloud broke over Veſuvius, and formed a tremendous torrent of mud, which took its courſe acroſs the great road between Torre del Greco and the Torre dell' Annunziata, and deſtroyed many vineyards, the late eruption could not be ſaid to have finiſhed, although the force of it was over the 22d of June. The power of attraction in mountains is well known; but whether the attractive power of a volcanic mountain is greater than that of any other mountain, is a queſtion. During this laſt eruption, however, it appeared that every watery cloud was evidently attracted by Veſuvius, and the ſudden diſſolution of thoſe clouds left marks of their deſtructive power on the face of the country all round the baſis of the volcano. Since the mouth of Veſuvius was enlarged, our author ſays he has ſeen a great cloud paſſing over it, and which not only was attracted, but was ſucked in, and diſappeared in a moment.

After every violent eruption of Mount Veſuvius, we read of damage done by a mephitic vapour, which coming from under the ancient lavas, inſinuates itſelf into low places, ſuch as the cellars and wells of the houſes ſituate at the foot of the volcano. After the eruption of 1767, there were ſeveral inſtances, as in this, of people going into their cellars at Portici, and other parts of that neighbourhood, having been ſtruck down by this vapour, and who would have expired if they had not been haſtily removed. Theſe occaſional vapours, or *moſete*, are of the ſame quality as that permanent one in the Grotta del Cane, near the lake of Agnano, and which has been proved to be chiefly fixed air. The vapours, that in the volcanic language of Naples, are called *fumaroli*, are of another nature, and iſſue from ſpots all over the freſh and hot lavas while they are cooling; they are ſulphureous and ſuffocating, ſo much ſo, that often the birds which are flying over them are overpowered, and fall down dead. Theſe vapours depoſit a cruſt of ſulphur, or ſalts, particularly of ſal ammoniac, on the ſcoriæ of the lava through which they paſs; and the ſmall cryſtals of which they are compoſed are often tinged with deep or pale yellow, with a bright red like cinnabar, and ſometimes with green, or an azure blue. After the late eruption, many pieces of the ſcoriæ of the freſh lava were found powdered with a lucid ſubſtance, exactly like the brighteſt ſteel or iron filings.

The firſt appearance of the moſete, after the late eruption, was on the 17th of June, when a peaſant going with an aſs to his vineyard, a little above the village of Reſina, in a narrow hollow way, the aſs dropped down, and ſeemed to be expiring; the peaſant was ſoon ſenſible of the mephitic vapour himſelf, and well knowing its fatal effects, dragged the animal out of its influence, and it ſoon recovered. This heavy vapour, when expoſed to the open air, does not riſe much more than a foot above the ſurface of the earth, but when it gets into a confined place, like a cellar or well, it riſes and fills as any other fluid would do; having filled a well, it riſes above it about a foot high, and then bending over, falls to the earth, on which it ſpreads, always preſerving its uſual level. Whereever this vapour iſſues, a wavering in the air is perceptible, like that which is produced by the burning of charcoal; and when it iſſues from a fiſſure near any plants or vegetables, the leaves of thoſe plants are ſeen to move, as if they were agitated by a gentle wind. It is extraordinary, that although there does not appear to be any poiſonous quality in this vapour, which in every reſpect reſembles fixed air, it ſhould prove ſo very fatal to the vineyards, ſome thouſand acres of which were deſtroyed by it after the late eruption: when it penetrates to the roots of the vines, it dries them up, and kills the plant. A peaſant in the neighbourhood of Reſina, having ſuffered by the moſete, which deſtroyed his vineyards in the year 1767, and having obſerved then that the vapour followed the laws of all fluids, made a narrow deep ditch all round his vineyard, which communicated with ancient lavas, and alſo with a deep cavern under one of them; the conſequence of his well reaſoned operation was, that although ſurrounded by theſe noxious vapours, which lay conſtantly at the bottom of his ditch, they never entered his vineyard, and his vines were in a flouriſhing ſtate, while thoſe of his neighbours were periſhing. Upwards of thirteen hundred hares, and many pheaſants and partridges, overtaken by this vapour, were found dead within his Sicilian majeſty's reſerved chaſes in the neighbourhood of Veſuvius; and alſo many domeſtic cats, who in their purſuit after this game fell victims to the moſete. A ſhoal of fiſh, of ſeveral hundred weight, having been obſerved by ſome fiſhermen at Reſina in great agitation on the ſurface of the ſea, near ſome rocks of an ancient lava that had run into the ſea, they ſurrounded them with their nets, and took them all with eaſe, and afterwards diſcovered that they had been ſtunned by the mephitic vapour, which at that time iſſued forcibly from underneath the ancient lava into the ſea.

The account of Sir William Hamilton is concluded by two remarks, which as they are curious I ſhall inſert:—

1. Within a mile of Caſtel-a-mare, the moſete were ſtill very active (on Sept. 2.) and particu-

larly under the ſpot where the ancient town of Stabia was ſituated. The 24th of Auguſt, a young lad by accident falling into a well there that was dry, but full of the mephitic vapour, was immediately ſuffocated; there were no ſigns of any injury from the fall, as the well was ſhallow. This circumſtance called to our author's mind the death of the elder Pliny, who moſt probably loſt his life by the ſame ſort of mephitic vapours, on this very ſpot, and which are active after great eruptions of Veſuvius.

2. Mr. James, a Britiſh merchant, aſſured our author, that on Tueſday night, the 17th of June, which was the third day of the eruption of Mount Veſuvius, he was in a boat with a ſail, near Torre del Greco, when the minute aſhes, ſo often mentioned, fell thick; and that in the dark they emitted a pale light like phoſphorus, ſo that his hat, thoſe of the boatmen, and the part of the ſails that were covered with aſhes, were luminous. Others have mentioned the having ſeen a phoſphoric light on Veſuvius after this eruption; but until it was confirmed to him by Mr. James, he did not chuſe to ſay any thing about it *.'

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* See Phil. Tranſ. for 1795, p. 73, &c.

CHAP. XLVI.

EARTHQUAKES.

Connection between Earthquakes and Volcanoes.—Earthquakes cauſed by the Progreſs of Steam between the Strata of the Earth.—Signs of approaching Earthquakes.—Great Earthquake at Liſbon, in 1755.—*Earthquakes in Calabria, in* 1783.

THE ſudden explosions which take place from volcanoes, probably depend on the acceſs of a quantity of water, which enters through ſome fiſſure communicating with the ſea, or which is derived from other ſources in the earth. If this maſs of water is ſufficiently great, it will extinguiſh the volcano; if not, it will be converted into ſteam, the expanſive force of which far exceeds that of gunpowder. The elaſtic fluid, thus formed, either finds vent at the mouth of the volcano, or, if the ſuperincumbent weight ſhould be too great, it will force a paſſage between the ſtrata of the earth, and occaſion that undulatory but ſometimes violent motion which is called an earthquake. From various facts demonſtrative of the coheſion and elaſticity of bodies, we are warranted in concluding, that the different ſtrata of which the earth is compoſed will adhere together, and that a freer paſſage will be afforded to any intervening body between the ſtrata than directly through them. If the confined fire acts directly under a province or town, it will heave the earth perpendicularly upwards, and the ſhocks will be more ſudden and violent. If it acts at a diſtance, it will raiſe that tract obliquely, and the motion will be more oblique, undulatory, and tremulous.

The great earthquake at Liſbon, in 1755, was felt as far as Scotland, and from the phenomena which attended it, it was evident that the ground had a waving motion from ſouth to north. All the oblong lakes, that lay from north to ſouth, were much agitated, the wave commencing at the ſouth end, whilſt all other lakes which lay acroſs, from eaſt to weſt, were much leſs affected.

The great diſtance to which earthquakes extend depends on the compreſſibility and elaſticity of the earth, which may be underſtood from the vibration of the walls of houſes, occaſioned by the paſſing of carriages in the adjacent ſtreets. Another inſtance is the vibration of ſteeples by the ringing of bells or guſts of wind. The Eddiſtone lighthouſe often vibrates from the force of the waves which beat againſt its foundation.

Previous to an eruption of Veſuvius the earth always trembles, and ſubterraneous exploſions are heard. On the 1ſt of November, 1755, the era ſo fatal to Liſbon, the iſland of Madeira was violently ſhaken by an earthquake, accompanied with ſubterraneous exploſions. So thoroughly convinced, indeed, are the inhabitants of volcanic countries of the connection between earthquakes and volcanoes, that when a great eruption takes place from a volcano,

they

they congratulate themſelves on having eſcaped an earthquake.

Earthquakes as well as volcanic eruptions are always preceded by a violent agitation of the ſea. Previous to the breaking out of Veſuvius, the ſea retires from the adjacent ſhores till the mountain is burſt open, and then it returns with ſuch impetuoſity as to overflow its uſual boundary. About an hour after the firſt ſhocks, which alarmed the city of Liſbon in 1755, the ſea was obſerved to come ruſhing towards the city like a torrent, though againſt both wind and tide; it roſe forty feet higher than was ever known, and as ſuddenly ſubſided. A ſhip, fifty leagues off at ſea, received ſo violent a ſhock as greatly to injure the deck, &c. The ſame effect was obſerved at Cadiz, and at a variety of ports throughout the Mediterranean, and, indeed, more or leſs, all over Europe.

That earthquakes are the effect of ſteam generated within the bowels of the earth, and that they are produced in the manner which has been deſcribed, appears highly probable from the quantities of ſteam and boiling water which have occaſionally been thrown up by volcanoes in different parts of the world. In 1631 and 1698 vaſt torrents of boiling water flowed from the crater of Veſuvius, previous to the eruption of fire: and what was, perhaps, ſtill more remarkable, many ſpecies of ſea-ſhells, in a calcined ſtate, were found on the brink of the crater, and alſo in the channel formed by the flood. The ſame thing happened at Ætna, in 1755, when a dreadful torrent of boiling water flowed from the crater at the time of an eruption of fire. Sir William Hamilton obſerves, that the ſea-ſhells emitted along with the water clearly indicate a communication with the ſea. All warm ſprings probably receive their heat from the action of pyrites, near which the water paſſes.

The following account of the great Liſbon earthquake is extracted from a volume of letters, publiſhed a few years ago by the reverend Mr. Davy:

'There never was a finer morning ſeen than the firſt of November (1755); the ſun ſhone out in its full luſtre; the whole face of the ſky was perfectly ſerene and clear, and not the leaſt ſignal or warning of that approaching event, which has made this once flouriſhing, opulent, and populous city, a ſcene of the utmoſt horror and deſolation, except only ſuch as ſerved to alarm, but ſcarcely left a moment's time to fly from the general deſtruction.

'It was on the morning of this fatal day, between the hours of nine and ten, that I was ſat down in my apartment, juſt finiſhing a letter, when the papers and table I was writing on began to tremble with a gentle motion, which rather ſurprized me, as I could not perceive a breath of wind ſtirring; whilſt I was reflecting with myſelf what this could be owing to, but without having the leaſt apprehenſion of the real cauſe, the whole houſe began to ſhake from the very foundation, which at firſt I imputed to the rattling of ſeveral coaches in the main ſtreet, which uſually paſſed that way, at this time, from Belem to the palace; but on hearkening more attentively, I was ſoon undeceived, as I found it was owing to a ſtrange frightful kind of noiſe under ground, reſembling the hollow diſtant rumbling of thunder; all this paſſed in leſs than a a minute, and I muſt confeſs I now began to be alarmed, as it naturally occurred to me, that this noiſe might poſſibly be the forerunner of an earthquake, as one I remembered, which had happened about ſix or ſeven years ago, in the Iſland of Madeira, commenced in the ſame manner, though it did little or no damage.

'Upon this I threw down my pen, and ſtarted upon my feet, remaining a moment in ſuſpenſe, whether I ſhould ſtay in the apartment, or run into the ſtreet, as the danger in both places ſeemed equal; and ſtill flattering myſelf that this tremor might produce no other effects than ſuch inconſiderable ones as had been felt at Madeira; but in a moment I was rouſed from my dream, being inſtantly ſtunned with a moſt horrid craſh, as if every edifice in the city had tumbled down at once. The houſe I was in ſhook with ſuch violence, that the upper ſtories immediately fell, and though my apartment (which was the firſt floor) did not then ſhare the ſame fate, yet every thing was thrown out of its place in ſuch a manner, that it was with no ſmall difficulty I kept my feet, and expected nothing leſs than to be ſoon cruſhed to death, as the walls continued rocking to and fro in the frightfulleſt manner, opening in ſeveral places, large ſtones falling down on every ſide from the cracks, and the ends of moſt of the rafters ſtarting out from the roof.

To add to this terrifying ſcene, the ſky in a moment became ſo gloomy, that I could now diſtinguiſh no particular object; it was an Egyptian darkneſs indeed, ſuch as might be felt; owing, no doubt, to the prodigious clouds of duſt and lime, raiſed from ſo violent a concuſſion, and as ſome reported, to ſulphureous exhalations, but this I cannot affirm; however, it is certain I found myſelf almoſt choaked for near ten minutes.

‘ As ſoon as the gloom began to diſperſe, and the violence of the ſhock ſeemed pretty much abated, the firſt object I perceived in the room was a woman ſitting on the floor, with an infant in her arms, all covered with duſt, pale and trembling; I aſked her how ſhe got hither: but her conſternation was ſo great that ſhe could give me no account of her eſcape; I ſuppoſe, that when the tremor firſt began, ſhe ran out of her own houſe, and finding herſelf in ſuch imminent danger from the falling of ſtones, retired into the door of mine, which was almoſt contiguous to her's, for ſhelter, and when the ſhock increaſed, which filled the door with duſt and rubbiſh, ran up ſtairs into my apartment, which was then open: be it as it might, this was no time for curioſity. I remember the poor creature aſked me, in the utmoſt agony, if I did not think that the world was at an end; at the ſame time ſhe complained of being choaked, and begged for God's ſake I would procure her a little drink; upon this I went to a cloſet where I kept a large jar with water (which you know is ſometimes a pretty ſcarce commodity in Liſbon) but finding it broken in pieces, I told her ſhe muſt not now think of quenching her thirſt, but ſaving her life, as the houſe was juſt falling on our heads, and if a ſecond ſhock came, would certainly bury us both; I bade her take hold of my arm, and that I would endeavour to bring her into ſome place of ſecurity.

'I ſhall always look upon it as a particular providence, that I happened on this occaſion to be undreſſed, for had I dreſſed myſelf, as I propoſed, when I got out of bed, in order to breakfaſt with a friend, I ſhould, in all probability, have run into the ſtreet at the beginning of the ſhock, as the reſt of the people in the houſe did, and conſequently have had my brains daſhed out, as every one of them had; however, the imminent danger I was in did not hinder me from conſidering that my preſent dreſs, only a gown and ſlippers, would render my getting over the ruins almoſt impracticable: I had, therefore, ſtill preſence of mind enough left to put on a pair of ſhoes and a coat, the firſt that came in my way, which was every thing I ſaved, and in this dreſs I hurried down ſtairs, the woman with me, holding by my arm, and made directly to that end of the ſtreet which opens to the Tagus, but finding the paſſage this way entirely blocked up with the fallen houſes to the height of their ſecond ſtories, I turned back to the other end which led into the main ſtreet (the common thoroughfare to the palace) and having helped the woman over a vaſt heap of ruins, with no ſmall hazard to my own life, juſt as we were going into the ſtreet, as there was one part I could not well climb over without the aſſiſtance of my hands, as well as feet, I deſired her to let go her hold, which ſhe did, remaining two or three feet behind me, at which time there fell a vaſt ſtone, from a tottering wall, and cruſhed both her and the child in pieces: ſo diſmal a ſpectacle at any other time would have affected me in the higheſt degree, but the dread I was in of ſharing the ſame fate myſelf, and the many inſtances of the ſame kind which preſented themſelves all around, were too ſhocking to make me dwell a moment on this ſingle object.

'I had now a long narrow ſtreet to paſs, with the houſes on each ſide four or five ſtories high, all very old, the greater part already thrown down, or continually falling, and threatening the paſſengers with inevitable death at every ſtep, numbers of whom lay killed before me, or what I thought far more deplorable—ſo bruiſed and wounded that they could not ſtir to help themſelves. For my own part, as deſtruction appeared to me unavoidable, I only wiſhed I might be made an end of at once, and not have my limbs broken, in which caſe I could expect nothing elſe but to be left upon the ſpot, lingering in miſery, like theſe poor unhappy wretches, without receiving the leaſt ſuccour from any perſon.

'As ſelf-preſervation, however, is the firſt law of nature, theſe ſad thoughts did not ſo far prevail, as to make me totally deſpair. I proceeded on as faſt as I conveniently could, though with the utmoſt caution, and having at length got clear of this horrid paſſage, I found myſelf ſafe and unhurt in the large open ſpace before St. Paul's church, which had been thrown down a few minutes before, and buried a great part of the congregation, that was generally pretty numerous, this being reckoned one of the moſt populous pariſhes in Liſbon. Here I ſtood ſome time, conſidering what I ſhould do, and not thinking myſelf ſafe in this ſituation, I came to the reſolution of climbing over the ruins of the weſt end of the church, in order to get to the river ſide, that I might be removed, as far as poſſible, from the tottering houſes, in caſe of a ſecond ſhock.

'This, with ſome difficulty, I accompliſhed, and here I found a prodigious concourſe of people, of both ſexes, and of all ranks and conditions, among whom I obſerved ſome of the principal canons of the patriarchal church, in their purple robes and rochets, as theſe all go in the habit of biſhops; ſeveral prieſts who had run from the altars in their ſacerdotal veſtments in the midſt of their celebrating maſs; ladies half dreſſed, and ſome without ſhoes; all theſe, whom their mutual dangers had here aſſembled as to a place of ſafety, were on their knees at prayers, with the terrors of death in their countenances, every one ſtriking his breaſt, and crying out inceſſantly, *Miſerecordia meu Dios.*

'In the midſt of our devotions, the ſecond great ſhock came on, little leſs violent than the firſt, and completed the ruin of thoſe buildings which had been already much ſhattered. The conſternation now became ſo univerſal, that the ſhrieks and cries of *Miſerecordia* could be diſtinctly heard from the top of St. Catherine's hill, at a conſiderable diſtance off, whither a vaſt number of people had likewiſe retreated; at the ſame time we could hear the fall of the pariſh church there, whereby many perſons were killed on the ſpot, and others mortally wounded. You may judge of the force of this ſhock, when I inform you, it was ſo violent, that I could ſcarce keep on my knees, but it was attended with ſome circumſtances ſtill more dreadful than the former.—On a ſudden I heard a general outcry, ‘The ſea is coming in, we ſhall be all loſt.’—Upon this, turning my eyes towards the river, which in that place is near four miles broad, I could perceive it heaving and ſwelling in a moſt unaccountable manner, as no wind was ſtirring; in an inſtant there appeared, at ſome ſmall diſtance, a large body of water, riſing like a mountain; it came on foaming and roaring, and ruſhed towards the ſhore with ſuch impetuoſity, that we all immediately ran for our lives, as faſt as poſſible; many were actually ſwept away, and the reſt above their waiſt in water at a good diſtance from the banks. For my own part, I had the narroweſt eſcape, and ſhould certainly have been loſt, had I not graſped a large beam that lay on the ground, till the water returned to its channel, which it did almoſt at the ſame inſtant, with equal rapidity. As there now appeared at leaſt as much danger from the ſea as the land, and I ſcarce knew whither to retire for ſhelter, I took a ſudden reſolution of returning back with my cloaths all dropping, to the area of St. Paul's: here I ſtood ſome time, and obſerved the ſhips tumbling and toſſing about, as in a violent ſtorm; ſome had broken their cables, and were carried to the other ſide of the Tagus; others were whirled round with incredible ſwiftneſs; ſeveral large boats were turned keel upwards; and all this without any wind, which ſeemed the more aſtoniſhing. It was at the time of which I am now ſpeaking, that the fine new quay, built entirely of rough marble, at an immenſe expence, was entirely ſwallowed up, with all the people on it, who had fled thither for ſafety, and had reaſon to think themſelves out of danger in ſuch a place; at the ſame time a great number of boats and ſmall veſſels, anchored near it (all likewiſe full of people, who had retired thither for the ſame purpoſe) were all ſwallowed up, as in a whirlpool, and never more appeared.

'This laſt dreadful incident I did not ſee with my own eyes, as it paſſed three or four ſtones throws from the ſpot where I then was, but I had the account as here given from ſeveral maſters of ſhips, who were anchored within two or three hundred yards of the quay, and ſaw the whole cataſtrophe. One of them in particular informed me, that when the ſecond ſhock came on, he could perceive the *whole* city waving backwards and forwards, like the ſea when the wind firſt begins to riſe; that the agitation of the earth was ſo great even under the river, that it threw up his large anchor from the mooring, which ſwam, as he termed it, on the ſurface of the water; that immediately upon this extraordinary concuſſion, the river roſe at once near twenty feet, and in a moment ſubſided; at which inſtant he ſaw the quay, with the whole concourſe of people upon it, ſink down; and at the ſame time every one of the boats and veſſels that were near it were drawn into the cavity, which he ſuppoſes inſtantly cloſed upon them, inaſmuch as not the leaſt ſign of a wreck was ever ſeen afterwards. This account you may give full credit to, for as to the loſs of the veſſels, it is confirmed by every body; and with regard to the quay, I went myſelf a few days after, to convince myſelf of the truth, and could not find even the ruins of a place, where I had taken ſo many agreeable walks, as this was the common rendezvous of the factory in the cool of the evening. I found it all deep water, and in ſome parts ſcarcely to be fathomed.

'This is the only place I could learn which was ſwallowed up in or about Liſbon, though I ſaw many large cracks and fiſſures in different parts, and one odd phenomenon I muſt not omit, which was communicated to me by a friend who has a houſe and wine-cellars on the other ſide of the river, viz. that the dwelling-houſe being firſt terribly ſhaken, which made all the family run out, there preſently fell down a vaſt high rock near it, that upon this the river roſe and ſubſided in the manner already mentioned, and immediately a great number of ſmall fiſſures appeared in ſeveral contiguous pieces of ground, whence there ſpouted out like a *jet d' eau* a large quantity of fine white ſand, to a prodigious height.

'I had not been long in the area of St. Paul's, when I felt the third ſhock, which though ſomewhat leſs violent than the two former, the ſea ruſhed in again, and retired with the ſame rapidity, and I remained up to my knees in water, though I had gotten upon a ſmall eminence at ſome diſtance from the river, with the ruins of ſeveral intervening houſes to break its force. At this time I took notice the waters retired ſo impetuouſly, that ſome veſſels were left quite dry, which rode in ſeven fathom water: the river thus continued alternately ruſhing on and retiring ſeveral times together, in ſuch ſort, that it was juſtly dreaded Liſbon would now meet the ſame fate, which a few years ago had befallen the city of * Lima.

'Perhaps you may think the preſent doleful ſubject here concluded; but, alas! the horrors of the firſt of November, are ſufficient to fill a volume. As ſoon as it grew dark, another ſcene preſented itſelf little leſs ſhocking than thoſe already deſcribed—the whole city appeared in a blaze, which was ſo bright that I could eaſily ſee to read by it. It may be ſaid, without exaggeration, it was on fire at leaſt in an hundred different places at once, and thus continued burning for ſix days together, without intermiſſion, or the leaſt attempt being made to ſtop its progreſs.

'I could never learn, that this terrible fire was owing to any ſubterraneous eruption, as ſome reported, but to three cauſes, which all concurring at the ſame time, will naturally account for the prodigious havock it made; the firſt of November being All Saints Day, a high feſtival among the Portu-

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* This happened in 1746.

gueſe, every altar in every church and chapel (ſome of which have more than twenty) was illuminated with a number of wax tapers and lamps, as cuſtomary; theſe ſetting fire to the curtains and timber work that fell with the ſhock, the conflagration ſoon ſpread to the neighbouring houſes, and being there joined with the fires in the kitchen chimnies, increaſed to ſuch a degree, that it might eaſily have deſtroyed the whole city, though no other cauſe had concurred, eſpecially as it met with no interruption.

‘ But what would appear incredible to you, were the fact leſs public and notorious, is, that a gang of hardened villains, who had been confined, and got out of priſon when the wall fell, at the firſt ſhock, were buſily employed in ſetting fire to thoſe buildings, which ſtood ſome chance of eſcaping the general deſtruction.

‘ The fire, by ſome means or other, may be ſaid to have deſtroyed the whole city, at leaſt every thing that was grand or valuable in it; and the damage on this occaſion is not to be eſtimated.

‘ The whole number of perſons that periſhed, including thoſe who were burnt, or afterwards cruſhed to death whilſt digging in the ruins, is ſuppoſed, on the loweſt calculation, to amount to more than ſixty thouſand; and though the damage in other reſpects cannot be computed, yet you may form ſome idea of it, when I aſſure you, that this extenſive and opulent city, is now nothing but a vaſt heap of ruins, that the rich and poor are at preſent upon a level, ſome thouſands of families which but

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the day before had been eaſy in their circumſtances, being now ſcattered about in the fields, wanting every conveniency of life, and finding none able to relieve them.

‘ A few days after the firſt conſternation was over, I ventured down into the city, by the ſafeſt ways I could pick out, to ſee if there was a poſſibility of getting any thing out of my lodgings, but the ruins were now ſo augmented by the late fire, that I was ſo far from being able to diſtinguiſh the individual ſpot where the houſe ſtood, that I could not even diſtinguiſh the ſtreet, amidſt the mountains of ſtone and rubbiſh which roſe on every ſide. Some days after, I ventured down again with ſeveral porters, who, having long plied in theſe parts of the town, were well acquainted with the ſituation of particular houſes; by their aſſiſtance, I at laſt diſcovered the ſpot; but was ſoon convinced, that to dig for any thing there, beſides the danger of ſuch an attempt, would never anſwer the expence.

‘ On both the times when I attempted to make this fruitleſs ſearch, eſpecially the firſt, there came ſuch an intolerable ſtench from the dead bodies, that I was ready to faint away, and though it did not ſeem ſo great this laſt time, yet it had nearly been more fatal to me, as I contracted a fever by it, but of which, God be praiſed, I ſoon got the better. However, this made me ſo cautious for the future, that I avoided paſſing near certain places, where the ſtench was ſo exceſſive that people began to dread an infection: a gentleman told me, that going into the town a few days after the earthquake, he ſaw ſeveral bodies lying in the ſtreets, ſome horribly mangled, as he ſuppoſed, by the dogs, others half burnt, ſome quite roaſted; and that in certain places, particularly near the doors of churches, they lay in vaſt heaps piled one upon another.'

The year 1783 was fatally marked by the deſolation of ſome of the moſt fertile, moſt beautiful, and moſt celebrated provinces of Europe. The two Calabrias, with a part of Sicily, were doomed to be a ſcene of the moſt tremendous, and the moſt fatal earthquakes that ever were known, even in thoſe volcanic regions. The firſt ſhock happened about noon, on the 5th of February, and was ſo violent as to involve almoſt the whole of Calabria in ruin. This was but the commencement of a ſucceſſion of earthquakes, which beginning from the city of Amantea, on the coaſt of the Tyrrhene ſea, proceeded along the weſtern coaſt to Cape Spartivento, and up the eaſtern as far as Cape D'Alice; during the whole of which ſpace not a town was left undeſtroyed.

During two years repeated ſhocks continued to agitate the affrighted minds of the inhabitants of Calabria and Sicily, but the principal miſchiefs aroſe in the months of February and March in the firſt year. For ſeveral months the earth continued in an unceaſing tremor, which at certain intervals increaſed to violent ſhocks, ſome of which were beyond deſcription dreadful. Theſe ſhocks were ſometimes horizontal, whirling like a vortex; and ſometimes by pulſations or beating from the bottom upwards, and were at times ſo violent that the heads of the largeſt trees almoſt touched the ground on either ſide. The rains, during a great part of the time, were continual and violent, often accompanied with lightning, and furious guſts of wind. All that part of Calabria, which lay between the 38th and 39th degrees, aſſumed a new appearance. Houſes, churches, towns, cities, and villages, were buried in one promiſcuous ruin. Mountains were detached from their foundations, and carried to a conſiderable diſtance *. Rivers diſappeared from their beds, and again returned and overflowed the adjacent country †. Streams of water ſuddenly guſhed out of the ground, and ſprang to a conſiderable height. Large pieces of the ſurface of the plain, ſeveral acres

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* Sir William Hamilton, whoſe ardent and laudable ſpirit of inquiry occaſioned his viſiting Calabria and Sicily during this calamitous ſeaſon, accounts for the removal of a mountain of about two hundred and fifty feet in heighth, and about four hundred feet in diameter at its baſis, from the different nature of its inferior and ſuperior ſtrata. The under part being more ſolid and compact, was more ſtrongly acted upon by the violent motion of the earth, and the volcanic exhalations, which drove it to the diſtance of ſome hundred yards from its original ſcite, where it lay in confuſed blocks, after having left the ſuperior ſtratum, which, with its trees and vineyards, was carried in another direction to the diſtance of four miles.

† The ſame philoſopher accounts for this phenomenon by ſuppoſing the firſt impulſe of the earthquake to have come from the bottom upwards, which raiſing the ſurface of the ground, the rivers which are not deep muſt naturally diſappear; but the earth returning again with violence to its former level, the rivers muſt as naturally return and overflow their banks; at the ſame time the boggy grounds being ſuddenly depreſſed, would force out the water which lay hid under their ſurface.

acres in extent, were carried five hundred feet from their former ſituation down into the bed of the river, and left ſtanding at nearly the diſtance of a mile, ſurrounded by large plantations of olives and mulberry trees, and corn growing as well upon them as upon the ground from which they were ſeparated. Amidſt theſe ſcenes of devaſtation, the eſcapes of ſome of the unhappy ſufferers is extremely wonderful. Some of the inhabitants of houſes which were thrown to a conſiderable diſtance, were dug out from their ruins unhurt. But theſe inſtances were few, and thoſe who were ſo fortunate as to preſerve their lives in ſuch ſituations, were content to purchaſe exiſtence at the expence of broken limbs and the moſt dreadful contuſions.

During this calamitous ſcene, it is impoſſible to conceive the horrors and wretchedneſs of the unhappy inhabitants. The jaws of death were opened to ſwallow them up; ruin had ſeized all their poſſeſſions, and thoſe dear connections to which they might have looked for conſolation in their ſorrows, were for ever buried in the mercileſs abyſs. All was ruin and deſolation. Every countenance indicated the extremity of affliction and deſpair; and the whole country formed a wide ſcene of undeſcribable horror.

One of the moſt remarkable towns which was deſtroyed was Caſal Nuova, where the Princeſs Gerace Grimaldi, with more than four thouſand of her ſubjects, periſhed in the ſame inſtant. An inhabitant happening to be on the ſummit of a neighbouring hill at the moment of the ſhock, and looking earneſtly back to the reſidence of his family, could ſee no other remains of it than a white cloud which proceeded from the ruins of the houſes. At Bagnara, about three thouſand perſons were killed, and not fewer at Radicina and Palma. At Terra Nuova four thouſand four hundred periſhed; and rather more at Semniari. The inhabitants of Scilla eſcaped from their houſes on the celebrated rock of that name, and, with their prince, deſcended to a little harbour at the foot of the hill; but, in the courſe of the night, a ſtupendous wave, which is ſaid to have been driven three miles over land, on its return ſwept away the unfortunate prince, with two thouſand four hundred and ſeventy-three of his ſubjects. It is computed that not leſs than forty thouſand perſons periſhed by this earthquake.

BOOK VII.

OF WATER.

CHAP. I.

OF WATER IN GENERAL.

Water a Compound Body.—Three States of Water.—Water in a fluid State.—Florentine Experiment.—Vapour.—Experiments aſcertaining the Force of Vapour.—Steam Engine.—Ice.—Phenomena of Freezing.—Of Thawing.—Water expanded in the State of Ice.—Immenſe Force exerted by Water on paſſing to that State.—Why Ice is not perfectly tranſparent.

WATER was univerſally conſidered as a ſimple elementary ſubſtance till the chemiſts of the preſent age proved, by experiments, the ſubſtance of which has been ſtated in a preceding volume *, that it is in reality a compound body. Its principles have been aſcertained both by compoſition and decompoſition; and one hundred parts of water are found to conſiſt of eighty-five parts of oxygen, and fifteen of hydrogen, or the baſis of inflammable air.

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* Book V. Chap. I.

This very uſeful and neceſſary fluid preſents itſelf to our notice in three diſtinct forms, namely, in its liquid ſtate, in the ſtate of vapour or ſteam, and laſtly in its frozen ſtate. Of theſe I ſhall ſpeak in their order.

Water, when pure and in its fluid ſtate, is tranſparent, colourleſs, and without ſmell. It adheres to moſt bodies which come in contact with it, it pervades porous ſubſtances, diſſolves gummy and ſaline matters, and extinguiſhes fire.

Water, when fluid is not in its moſt ſimple ſtate, for its fluidity depends on a certain quantity of caloric, or the matter of heat, which enters into combination with it, and inſinuating itſelf between the particles of the water, renders them capable of moving in all directions.

We are ſupplied with water either from the atmoſphere, whence it deſcends in the form of rain, hail, or ſnow, or from the earth which ſends it forth in ſprings and rivulets. In the former caſe the watery exhalations drawn from the ſea, and the ſurface of the earth by the ſun's heat, form clouds, whoſe particles being afterwards condenſed, fall back again in ſhowers. In the latter, the water which falls on the tops of mountains, and other lofty ſituations, penetrates the earth, and, after paſſing downwards, breaks forth at ſome fiſſure or aperture at a diſtance from its ſource.

The quantity of water attracted from the ſurface of the globe is almoſt incredible. Dr. Halley has calculated that portion which is yielded by the ſea, to be at the rate of one cubic inch from every ten inches of ſurface in twelve hours *. To form an adequate idea of this, let us ſuppoſe only half the globe to be covered by the ſea. The whole ſurface of the earth being about 25,797,278 leagues, that of the ſea will conſequently be 12,898,639. Suppoſing the evaporation which takes place in twelve hours to be that above mentioned, without having any regard to what is evaporated from the whole of the land, or from the ſea during the other twelve hours, it will be found that the atmoſphere has taken up no leſs than 20,302,535,177,834, or more than twenty millions of millions of cubic feet of water; an enormous quantity, and much more than ſufficient to ſupply all the rivers that interſect the different quarters of the globe †.

What particularly diſtinguiſhes water, and thoſe fluids which are of a ſimilar conſiſtence, and in common language are termed liquids, from thoſe ſubtile fluids which were treated of at large in the preceding volume, is, that the former are not, like the others, poſſeſſed of that ſurprizing elaſticity

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[*] See Biſhop Watſon's Calculation, vol. i. p. 122.

[†] There will poſſibly be apparent, in this part of the work, ſome degree of repetition when compared with what was ſaid of vapour in the firſt book. It was then neceſſary to ſpeak of vapour, in explanation of the properties of heat; it is now neceſſary to treat of it in connection with the fluid of which it is uſually formed; and I conceive it better to do this, with the riſk of ſome repetition, than to refer to a former volume, both becauſe it will ſerve more firmly to impreſs on the minds of young readers ſome of the moſt important doctrines of philoſophy: and becauſe what may now appear as repetition, is, in this place, mixed with new facts, which could not be previouſly introduced.

which admits of the volume of fluid being condenſed into a ſmall compaſs; but, on the contrary, may be conſidered as incapable of compreſſion, or at leaſt are compreſſible in a very ſlight degree. The Florentine academicians filled a globe of gold with water, and compreſſed it with immenſe force; the firſt effect of this compreſſion was, that the ball was conſiderably heated by the emiſſion of latent heat from the water, and afterwards the fluid forced its way through the pores of the gold, or through certain cavities, and appeared in drops on the external ſurface. The concluſion, however, which was haſtily drawn from this experiment, that water, in its liquid ſtate, is abſolutely void of all elaſticity, is not warrantable. Since other experiments ſhew that water as well as mercury will yield, in a certain degree, to the preſſure of the air in a condenſing machine, as Mr. Canton proved by including it in a glaſs veſſel, with a narrow neck or ſtem nicely graduated; its condenſation appears proportioned to the force, and as ſoon as the preſſure of the air is removed, the fluid will be obſerved gradually to recover its accuſtomed dimenſions.

When water becomes heated to a degree beyond that of the air upon its ſurface, the matter of heat, which has a conſtant propenſity to diffuſe itſelf equally through all bodies with which it is in contact, riſes and carries with it part of the water, which it converts into an elaſtic fluid or vapour. Until the water, however, arrives at the boiling point, the evaporation is very gradual; but when this happens it becomes very rapid, and the part of the water which is moſt heated, being converted into vapour, riſes ſuddenly to the ſurface, and occaſions conſiderable agitation.

Ebullition requires a determined degree of heat, becauſe the ſteam cannot be formed within the water, unleſs it is ſtrong enough to overcome the actual preſſure of the fluid and air incumbent on it. But in ordinary evaporation, the vapour is formed at the ſurface of the water, and has therefore no other preſſure to overcome than that of the atmoſphere. The elaſtic fluid, however, which is formed by ordinary evaporation is different from that produced by ebullition, for the latter always returns to the ſtate of water by a diminution of temperature, whereas the former is reduced almoſt to the ſtate of a permanently elaſtic fluid by mixture with air.

We find that all fluids boil more eaſily in proportion as the preſſure of the atmoſphere is removed; whether this is effected by aſcending a mountain, or making uſe of the air pump. M. Lavoiſier ſays, that if the weight of the atmoſphere was only equal to between twenty or twenty-four inches of a column of mercury, inſtead of twenty-eight inches, we ſhould never be able to obtain æther in a liquid ſtate, at leaſt in ſummer; and that the formation of æther muſt conſequently be impoſſible upon mountains of a moderate degree of elevation, without employing extraordinary means of compreſſion for its condenſation. Upon the whole, it appears moſt probable that all bodies are capable of exiſting in a ſolid, a liquid, and an aeriform ſtate; that the firſt is the moſt ſimple ſtate of all bodies, and that the two others depend on combinations with different quantities of the matter of heat, of which the aeriform ſtate requires by far the moſt.

Vapour, as it firſt riſes from boiling water, is inviſible, but as it mixes with the air it is deprived of part of its heat, returns to its fluid form, and the very minute drops of water which are produced aſcend in a copious cloud of a white or light-grey colour. Vapour is the more readily diſcernable in proportion to the coldneſs and humidity of the atmoſphere. The cloudy appearance of ſteam is occaſioned by the difficulty with which its particles are ſeparated and diſſolved in the atmoſphere; the difficulty is increaſed in proportion to the coldneſs and humidity of the air, and this is the reaſon that the moiſture exhaled with the breath, is viſible in winter and not in ſummer.

It was ſtated in a former volume, that the combination of the matter of heat or caloric, with the particles of water, in that degree which conſtitutes ſteam, rarifies them ſo exceedingly, as to occaſion them to occupy a ſpace ſome hundred times greater than the original bulk of the fluid, and it is that alſo which volatilizes and enables them to aſcend through the air, and to overcome its reſiſtance.

But when ſteam is expoſed to a ſtill greater degree of heat, its volume is augmented ſtill more conſiderably. That heat which makes water boil, and which rarifies it only one twenty-ſixth, rarifies its vapour to eighteen hundred times the bulk of the water which produced it. This may be very readily demonſtrated, by taking a glaſs tube, at one end of which is a bulb of two inches in diameter, and dropping into it a ſingle drop of water, the diameter of which we will ſuppoſe to be one-tenth of an inch. The ſquares of theſe two ſpheres, with regard to each other, will be as 1800 are to one. Upon heating the bulb of the tube over the flame of a ſpirit lamp, the air will firſt be expelled, and afterwards the drop of water will be converted into ſteam, and take poſſeſſion of the whole of the bulb; as may be proved by plunging the mouth of the tube into cold water, and ſuffering the ſteam within the bulb to return to its fluid ſtate. In this caſe, the preſſure of the atmoſphere will cauſe the water to ruſh into the tube, and to occupy that ſpace within the bulb, which before was occupied by the vapour, and thus the fact will be aſcertained.

If, however, any obſtacle is oppoſed to the expanſive force of ſteam, the heat augments its reſiſtance in a degree proportionate to the augmentation of its volume. The power of reſiſtance afforded by the vapour of water is prodigious, and has of late years been made ſubſervient to ſome mechanical purpoſes of the greateſt importance. Muſchenbrook has proved by experiment, that the force of gunpowder is feeble, when compared to that of riſing ſteam. An hundred and forty pounds of gunpowder blew up a weight of thirty thouſand pounds; but on the other hand, an hundred and forty pounds of water, converted by heat into ſteam, lifted a weight of ſeventy-ſeven thouſand pounds, and would lift a much greater, if there were means of giving the ſteam greater heat with ſafety; for the hotter the ſteam the greater is its force.

The ſteam-engine, to which I had formerly occaſion ſlightly to advert*, is a machine which may be, and is occaſionally applied to various mechanical purpoſes where great force is required, but which has *hitherto* been principally uſed to clear mines from water, and to raiſe water to a proper height for the ſupply of cities. In theſe caſes, the expanſive power of ſteam is ſo managed as to operate on immenſe water pumps, which could not conveniently be worked by any other means. In order to give the reader a ſuperficial idea of this machine, let us imagine a common pump prepared, and that we want to move the handle of this pump upwards by the force of ſteam only. In the firſt place, let us ſuppoſe, that the handle of the pump, or ſomething connected to it, was ſo contrived as to admit of being inſerted in the barrel of a gun, or ſome cylindrical tube, ſet upright over a cauldron containing boiling water. Next let us ſuppoſe, that the ſteam could be admitted into the tube, through the touch-hole, and ſo confined as to paſs only by that way. Now as the fire begins to dilate the ſteam, a part of it will enter the tube by the touch-hole, and this will preſs up the pump, which is ſuppoſed to be ſo fitted to the tube as to prevent any part of the ſteam from eſcaping. In this way the pump handle would be driven quite out at the mouth of the tube, but let us imagine, that before this can happen a valve is opened, which allows a ſmall quantity of cold water to be ſpouted into the tube, which effectually and inſtantaneouſly deſtroys, or, more properly, condenſes the ſteam. The tube being now left empty, there is nothing to counteract the preſſure of the atmoſphere, which again forces down the handle into the tube, into which no ſteam is permitted to enter, on account of a valve which now ſtops the touch hole below; but when the handle is thus preſſed down, the valve below is again opened, and new ſteam entering again preſſes the handle upward; when the handle comes near the top, the ſteam is again cooled and condenſed as before, and the handle is again preſſed down by the weight of the atmoſphere. In this manner it is alternately driven upwards and downwards by the expanſive power of the ſteam and the preſſure of the external air, and works the pump with unwearied aſſiduity.

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* See vol. i. p. 110.

Though the principle, however, is plain, the machinery is complex in the ſteam engine; but the annexed plate IV. will probably render it tolerably intelligible.

In fig. 1. A repreſents the fire-place under the boiler, for the boiling of the water, and the aſh-hole below it.

B, the boiler, filled with water about three feet above the bottom, made of iron plates.

C, the ſteam pipe, through which the ſteam paſſes from the boiler into the receiver.

D, the receiver, a cloſe iron veſſel, in which is the regulator or ſteam-cock, which opens and ſhuts the hole of communication at each ſtroke.

E, the communication pipe between the receiver and the cylinder; it riſes five or ſix inches up, in the inſide of the cylinder bottom, to prevent the injected water from deſcending into the receiver.

F, the cylinder, of caſt iron, about ten feet long, bored ſmooth in the inſide; it has a broad flanch in the middle on the outſide, by which it is ſupported when hung in the cylinder beams.

G, the piſton, made to fit the cylinder exactly: it has a flanch riſing four or five inches upon its upper ſurface, between which and the ſide of the cylinder a quantity of junk or oakum is ſtuffed, and kept down by weights, to prevent the entrance of air or water and the eſcaping of ſteam.

H, the chain and piſton ſhank, by which it is connected to the working beam.

I I, the working beam or lever: it is made of two or more large logs of timber, bent together at each end, and kept at the diſtance of eight or nine inches from each other in the middle by the gudgeon, as repreſented in the plate. The arch-heads, I I, at the ends, are for giving a perpendicular direction to the chains of the piſton and pump-rods.

K, the pump-rod which works in the ſucking pump

L, and draws the water from the bottom of the pit to the ſurface.

M, a ciſtern, into which the water drawn out of the pit is conducted by a trough; ſo as to keep it always full; and the ſuperfluous water is carried off by another trough.

N, the jack-head pump; which is a ſucking-pump wrought by a ſmall lever or working-beam, by means of a chain connected to the great beam or lever near the arch *g* at the inner end; and the pump rod at the outer end. This pump commonly ſtands near the corner of the front of the houſe, and raiſes the column of water up to the ciſtern O, into which it is conducted by a trough.

O, the jack-head ciſtern for ſupplying the injection, which is always kept full by the pump N; it is fixed ſo high as to give the jet a ſufficient velocity into the cylinder when the cock is opened. This ciſtern has a pipe on the oppoſite ſide for conveying away the ſuperfluous water.

P P, the injection-pipe, of three or four inches diameter; which turns up in a curve at the lower end, and enters the cylinder bottom; it has a thin plate of iron upon the end *a*, with three or four adjutage holes in it, to prevent the jet of cold water of the jack-head ciſtern from flying up againſt the piſton, and yet to condenſe the ſteam each ſtroke, when the injection-cock is open.

e, a valve upon the upper end of the injection-pipe within the ciſtern, which is ſhut when the engine is not working, to prevent any waſte of the water.

f, a ſmall pipe which branches off from the injection-pipe, and has a ſmall cock to ſupply the piſton with a little water to keep it air-tight.

Q, the working plug, ſuſpended by a chain to the arch *g* of the working beam. It is uſually a heavy piece of timber, with a ſlit vertically down its middle, and holes bored horizontally through it, to receive pins for the purpoſe of opening and ſhutting the injection and ſteam cocks, as it aſcends and deſcends by the motion of the working beam.

h, the handle of the ſteam-cock or regulator. It is fixed to the regulator by a ſpindle which comes up through the top of the receiver. The regulator is a circular plate of braſs or caſt iron, which is moved horizontally by the handle *h*, and opens or ſhuts the communication at the lower end of the pipe E within the receiver. It is repreſented in the plate by a circular dotted line.

i i, the ſpanner, which is a long rod or plate of iron for communicating motion to the handle of the regulator, to which it is fixed by means of a ſlit in the latter, and ſome pins put through to faſten it.

k l, the vibrating lever, called the Y, having the weight *k* at one end and two legs at the other end. It is fixed to an horizontal axis, moveable about its center-pins or pivots *m n*, by means of the two ſhanks *o p* fixed to the ſame axis, which are alternately thrown backwards and forwards by means of two pins in the working plug; one pin on the outſide depreſſing the ſhank *o*, throws the loaded end *k* of the Y from the cylinder into the poſition repreſented in the plate, and cauſes the leg *l* to ſtrike againſt the end of the ſpanner, which, forcing back the handle of the regulator or ſteam cock, opens the communication, and permits the ſteam to fly into the cylinder. The piſton immediately riſing by the admiſſion of the ſteam, the working beam I I riſes; which alſo raiſes the working-plug, and another pin which goes through the ſlit raiſes the ſhank *p*, which throws the end *k* of the Y towards the cylinder, and, ſtriking the end of the ſpanner, forces it forward, and ſhuts the regulator ſteam-cock.

q r, the lever for opening and ſhutting the injection cock, called the F. It has two toes for its center, which take between them the key of the injection cock. When the working-plug has aſcended nearly to its greateſt height, and ſhut the regulator, a pin catches the end *q* of the F and raiſes it up, which opens the injection-cock, admits a jet of cold water to fly into the cylinder, and, condenſing the ſteam, makes a vacuum; then the preſſure of the atmoſphere bringing down the piſton in the cylinder, and alſo the plug-frame, another pin fixed in it catches the end of the lever in its deſcent, and, by preſſing it down, ſhuts the injection-cock, at the ſame time the regulator is opened to admit ſteam, and ſo on alternately; when the regulator is ſhut the injection is open, and when the former is open the latter is ſhut.

R, the hot-well, a ſmall ciſtern made of planks, which receives all the waſte water from the cylinder.

S, the ſink-pit to convey away the water which is injected into the cylinder at each ſtroke. Its upper end is even with the inſide of the cylinder bottom, its lower end has a lid or cover moveable on a hinge, which ſerves as a valve to let out the injected water, and ſhuts cloſe each ſtroke of the engine, to prevent the water being forced up again when the vacuum is made.

T, the feeding-pipe, to ſupply the boiler with water from the hot-well. It has a cock to let in a large or ſmall quantity of water, as occaſion requires, to make up for what is evaporated; it goes nearly down to the boiler bottom.

U, two gage cocks, the one larger than the other, to try when a proper quantity of water is in the boiler: upon opening the cocks, if one gives ſteam and the other water, it is right; if they both give ſteam, there is too little water in the boiler; and if they both give water, there is too much.

W, a plate which is ſcrewed on to a hole on the ſide of the boiler, to allow a paſſage into the boiler for the convenience of cleaning or repairing it.

X, the ſteam-clack or puppet valve, which is a braſs valve on the top of a pipe opening into the boiler, to let off the ſteam when it is too ſtrong. It is loaded with lead, at the rate of one pound to an inch ſquare; and when the ſteam is nearly ſtrong enough to keep it open, it will do for the working of the engine.

f, the ſnifting valve, by which the air is diſcharged from the cylinder each ſtroke, which was admitted with the injection, and would otherwiſe obſtruct the due operation of the engine.

t t, the cylinder-beams; which are ſtrong joiſts going through the houſe for ſupporting the cylinder.

v, the cylinder cap of lead, ſoldered on the top of the cylinder, to prevent the water upon the piſton from flaſhing over when it riſes too high.

w, the waſte-pipe, which conducts the ſuperfluous water from the top of the cylinder to the hot-well.

x x, iron bars, called the catch-pins, fixed horizontally through each arch head, to prevent the beam deſcending too low in caſe the chain ſhould break.

y y, two ſtrong wooden ſprings, to weaken the blow given by the catch pins when the ſtroke is too long.

z z, two friction-wheels, on which the gudgeon or center of the great beam is hung; they are the third or fourth part of a circle, and move a little each way as the beam vibrates. Their uſe is to diminiſh the friction of the axis, which, in ſo heavy a lever, would otherwiſe be very great.

When this engine is to be ſet to work, the boiler muſt be filled about three or four feet deep with water, and a large fire made under it; and when the ſteam is found to be of a ſufficient ſtrength by the puppet-clack, then by thruſting back the ſpanner, which opens the regulator or ſteam-cock, the ſteam is admitted into the cylinder, which raiſes the piſton to the top of the cylinder, and forces out all the air at the ſnifting valve; then by turning the key of the injection-cock, a jet of cold water is admitted into the cylinder, which condenſes the ſteam and makes a vacuum; and the atmoſphere then preſſing upon the piſton, forces it down to the lower part of the cylinder, and makes a ſtroke by raiſing the column of water at the other end of the beam. After two or three ſtrokes are made in this manner, by a man opening and ſhutting the cocks to try if they are right, then the pins may be put into the pin-holes in the working-plug, and the engine left to turn the cocks of itſelf, which it will do with greater exactneſs than any man can do.

Many important improvements have been lately made in the ſteam engine by the ingenious Mr. Watt, of Birmingham. He has contrived to preſerve an uniform heat in the cylinder of his engines, by ſuffering no cold water to touch it, and by protecting it from the air, or other cold bodies, by a ſurrounding caſe filled with ſteam, or with hot air or water, and by coating it over with ſubſtances that tranſmit heat ſlowly. He makes his vacuum to approach nearly to that of the barometer, by condenſing the ſteam in a ſeparate veſſel, called the condenſer, which may be cooled at pleaſure without cooling the cylinder, either by an injection of cold water, or by ſurrounding the condenſer with it, and generally by both. He extracts the injection water and detached air from the cylinder or condenſer by pumps, which are wrought by the engine itſelf, or blows them out by the ſteam. As the entrance of air into the cylinder would ſtop the operation of the engines, and as it is hardly to be expected that ſuch enormous piſtons as thoſe of ſteam engines can move up and down, and yet be abſolutely tight in the common engines, a ſtream of water is kept always running upon the piſton, which prevents the entry of the air; but this mode of ſecuring the piſton, though not hurtful in the common ones, would be highly prejudicial to the new engines. Their piſton is therefore made more accurately; and the outer cylinder, having a lid, covers it, the ſteam is introduced above the piſton; and when a vacuum is produced under it, acts upon it by its elaſticity, as the atmoſphere does upon common engines by its gravity. This way of working effectually excludes the air from the inner cylinder, and gives the advantage of adding to the power, by increaſing the elaſticity of the ſteam.

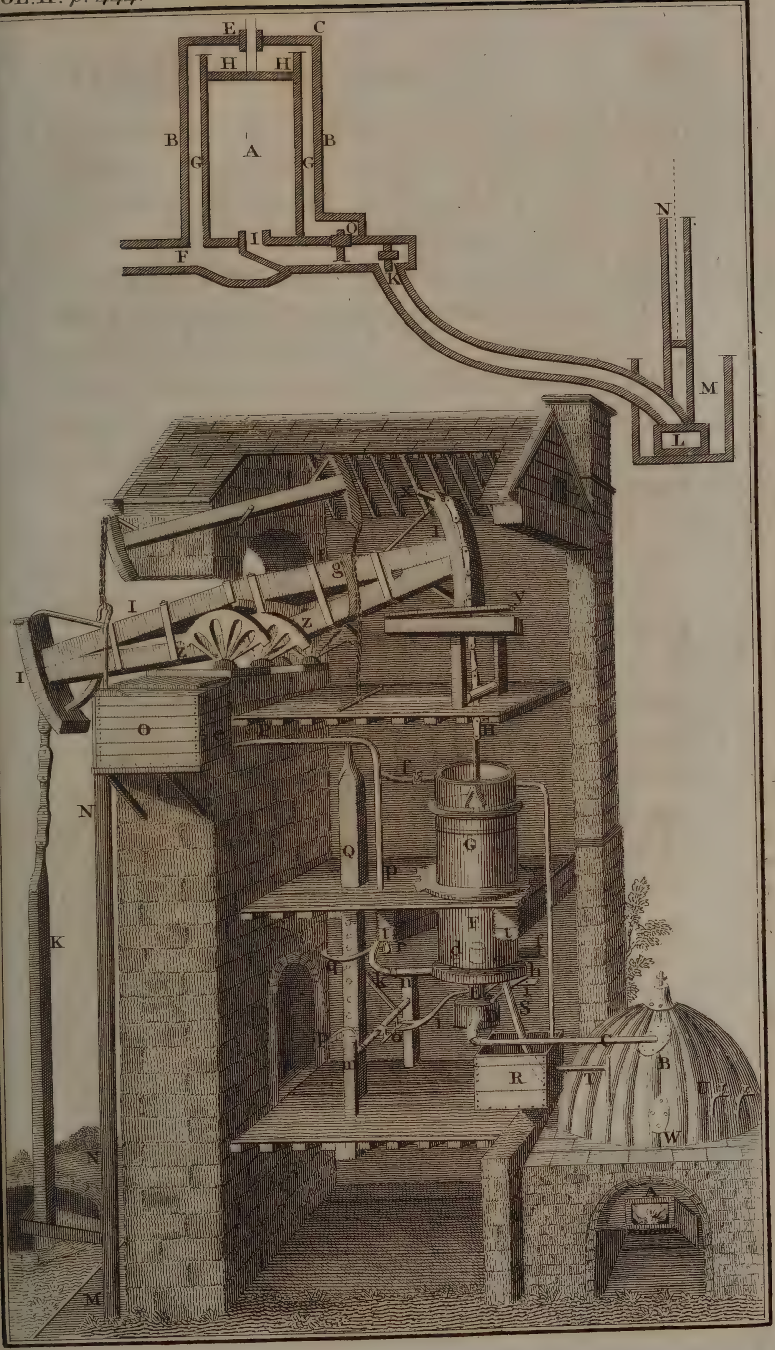
In Mr. Watt's engines, the cylinder, the great beams, the pumps, &c. ſtand in their uſual poſitions. The cylinder is ſmaller than uſual, in proportion to the load, and is very accurately bored.

In the moſt complete engines, it is ſurrounded, at a ſmall diſtance, with another cylinder, furniſhed with a bottom and a lid. The interſtice between the cylinders communicates with the boilers by a large pipe, open at both ends, ſo that it is always filled with ſteam, and thereby maintains the inner cylinder always of the ſame heat with the ſteam, and prevents any condenſation within it, which would be more detrimental than an equal condenſation in the outer one. The inner cylinder has a bottom and piſton as uſual; and as it does not reach up quite to the lid of the outer cylinder, the ſteam in the interſtice has always free acceſs to the upper ſide of the piſton. The lid of the outer cylinder has a hole in its middle; and the piſton rod, which is truly cylindrical, moves up and down through that hole, which is kept ſteam-tight by a collar of oakum ſcrewed down upon it. At the bottom of the inner cylinder, there are two regulating valves, one of which admits the ſteam to paſs from the interſtice into the inner cylinder below the piſton, or ſhuts it out at pleaſure; the other opens or ſhuts the end of a pipe, which leads to the condenſer. The condenſer conſiſts of one or more pumps furniſhed with clacks and buckets (nearly the ſame as in common pumps) which are wrought by chains faſtened to the great working beam of the engine. The pipe, which comes from the cylinder, is joined to the bottom of theſe pumps, and the whole condenſer ſtands immerſed in a ciſtern of cold water ſupplied by the engine. The place of this ciſtern is either within the houſe or under the floor, between the cylinder and the lever wall; or without the houſe between that wall and the engine ſhaft, as conveniency may require. The condenſer being exhauſted of air by blowing, and both the cylinders being filled with ſteam, the regulating valve which admits the ſteam into the inner cylinder is ſhut, and the other regulator which communicates with the condenſer is opened, and the ſteam ruſhes into the vacuum of the condenſer with violence; but there it comes into contact with the cold ſides of the pumps and pipes, and meets a jet of cold water, which was opened at the ſame time with the exhauſtion regulator; theſe inſtantly deprive it of its heat, and reduce it to water; and the vacuum remaining perfect, more ſteam continues to ruſh in, and be condenſed until the inner cylinder is exhauſted. Then the ſteam which is above the piſton, ceaſing to be counteracted by that which was below it, acts upon the piſton with its whole elaſticity, and forces it to deſcend to the bottom of the cylinder, and ſo raiſes the buckets of the pumps which are hung to the other end of the beam. The exhauſtion regulator is now ſhut, and the ſteam one opened again, which, by letting in the ſteam, allows the piſton to be pulled up by the ſuperior weight of the pump rods; and ſo the engine is ready for another ſtroke.

But the nature of Mr. Watt's improvement will be perhaps better underſtood from the following deſcription of it, as referred to a figure.—The cylinder or ſteam veſſel A, of this engine (fig. 2.) is ſhut at bottom and opened at top as uſual, and is included in an outer cylinder or caſe BB, of wood or metal, covered with materials which tranſmit heat ſlowly. This caſe is at a ſmall diſtance from the cylinder, and cloſe at both ends. The cover C has a hole in it, through which the piſton rod E ſlides; and near the bottom is another hole F, by which the ſteam from the boiler has always free entrance into this caſe or outer cylinder, and by the interſtice GG between the two cylinders has acceſs to the upper ſide of the piſton HH. To the bottom of the inner cylinder A is joined a pipe I, with a cock or valve K, which is opened and ſhut when neceſſary, and forms a paſſage to another veſſel L called a *condenſer*, made of thin metal. This veſſel is immerſed in a ciſtern M full of cold water, and it is contrived ſo as to expoſe a very great ſurface externally to the water, and internally to the ſteam. It is alſo made air-tight, and has pumps N wrought by the engine, which keep it always exhauſted of air and water.

Both the cylinders A and BB being filled with ſteam, the paſſage K is opened from the inner one to the condenſer L, into which the ſteam violently ruſhes by its elaſticity, becauſe that veſſel is exhauſted; but as ſoon as it enters it, coming into contact with the cold matter of the condenſer, it is reduced to water, and the vacuum ſtill remaining, the ſteam continues to ruſh in till the inner cylinder A below the piſton is left empty. The ſteam which is above the piſton, ceaſing to be counteracted by that which is below it, acts upon the piſton HH, and forces it to deſcend to the bottom of the cylinder, and ſo raiſes the bucket of the pump by means of the lever. The paſſage K between the inner cylinder and the condenſer is then ſhut, and another paſſage O is opened, which permits the ſteam to paſs from the outer cylinder, or from the boiler into the inner cylinder under the piſton; and then the ſuperior weight of the bucket and pump rods pulls

Plate 4.



pulls down the outer end of the lever or great beam, and raiſes the piſton, which is ſuſpended to the inner end of the ſame beam.

When water is expoſed to a cold atmoſphere, it firſt loſes its free caloric, and is reduced in temperature, but no part of it begins to freeze till the maſs is reduced ſomewhat below the thirty-ſecond degree of Fahrenheit's thermometer; a ſmall quantity of the water then becomes ſolid, which, by changing its ſtate, ſets at liberty a quantity of its combined heat, which reſtores the water in contact with it to the temperature of 32 degrees, or rather above it. The congelation is therefore at a ſtand till this ſenſible heat is abſtracted by the atmoſphere, and the maſs again reduced ſomewhat below the thirty-ſecond degree. Another portion of water then congeals, and the proceſs is again ſtopped by the emiſſion of heat. In this manner congelation pervades the whole maſs, and is performed at intervals, which are very obſervable when the phenomenon of freezing is accurately attended to.

The ſame law operates in the paſſage of other bodies from the ſtate of fluids to that of ſolids, and the contrary. Dr. Irvine has ſhewn, that when ſpermaceti and wax are melted, they contain heat in a combined or latent ſtate. By heating them much above their point of fluidity, he found that they loſt their heat very ſoon, till ſome parts became ſolid; after this they continued of exactly the ſame temperature till the whole became ſolid, though expoſed all the while to cold air; but when all became ſolid they cooled as they did at firſt. In the ſame manner water mixed with ice, whatever may be the temperature of the ſurrounding medium, and whether the quantity of ice is increaſing or diminiſhing, always nearly preſerves the temperature of 32 degrees.

The freezing of water was formerly attributed to the entrance of frigorific particles into that fluid; but the above doctrine, founded on the great diſcoveries of Dr. Black, is almoſt univerſally deemed ſo ſatisfactory as to have left the other, which is a mere hypotheſis, ſcarcely a ſingle advocate. The augmentation of the bulk of water in freezing ſeems to be the only fact which can with reaſon be alledged in ſupport of the doctrine of frigorific particles; but this increaſe of bulk is not attended with any increaſe of weight, and may be much better explained, than by attributing it to the addition of frigorific particles, which were never proved to have any exiſtence.

The increaſe which water acquires in becoming ſolid is about one-ninth or one-tenth of its whole bulk. Boyle took a braſs tube, three inches in diameter, and put ſome water into it; he then brought down into the tube a plug with a weight placed at the head of it of ſeventy-four pounds. On expoſing the tube to the cold, the water freezing and expanding itſelf, raiſed the ſeventy-four pounds. The expanſive power of water, in the proceſs of freezing, was proved by a remarkable experiment made in Canada. An iron ſhell, after having its mouth well plugged up, was filled up with water and expoſed to a ſevere froſt which prevailed in that country. The expanſion of the ice forced out the plug, and the water, which immediately followed, was frozen into an irregular maſs or column of ice. The inſtances, however, already mentioned, are far leſs ſtriking than one deſcribed by Muſchenbroëck, in which a ball of iron, an inch thick, was burſt aſunder in the courſe of twelve hours by the expanſive power of froſt. That philoſopher having calculated the force exerted by the freezing of water in a ſimilar caſe, found it equal to a force capable of raiſing a weight of twenty-ſeven thouſand ſeven hundred and twenty pounds. That the expanſive power of freezing water, however, has certain limits, appears from the following experiment, made by the Florentine academicians. A braſs globe filled with water, and cloſed at its orifice by a well-fitted ſcrew, was immerſed in freezing water, but did not burſt; they then pared off ſuch a quantity of the metal as left the ſides of the globe unable to reſiſt the expanſion of the water; the force which was required to burſt the globe in this ſtate was computed at twenty-ſeven thouſand pounds. When ſuch is the expanſive power exerted by water in paſſing to the ſtate of ice, we cannot be ſurprized that veſſels, which are left filled with water in froſty weather, ſhould be burſt by its freezing, and that the ſame thing ſhould happen to water-pipes expoſed to the action of froſt. The pavement is ſometimes looſened from the ſame cauſe, and in countries where very ſevere colds prevail, the ſap of trees congeals, and their trunks are burſt aſunder with a noiſe like that of cannon.

Froſt fertilizes the ground, by looſening the coheſion of the particles of earth.

As ice is never perfectly clear or tranſparent, and as we find ſmall cavities in it, ſome have thought that the air inſinuates itſelf; but this has been refuted by water being frozen under an exhauſted receiver, and the ſame cavities being found in the ice. The ice, in fact, inſtead of being heavier, was found to be lighter. The expanſion of ice, indeed, is evidently owing to the cryſtallization of the water, and the particles aſſuming a different arrangement, and not being in cloſe contact. If this is admitted, as I apprehend it muſt, we cannot ſay, with propriety, that the ſolid particles of water expand. The ſpiculæ, of which ice conſiſts, cut each other at angles of ſixty or one hundred and twenty degrees.

When it ſnows at Moſcow, and the air is not too dry, it is obſerved to be loaded with beautiful cryſtallizations, regularly flattened, and as thin as a leaf of paper. They conſiſt of an union of fibres, which ſhoot from the center to form ſix principal rays, which are themſelves divided into extremely ſmall blades.

It appears, however, that the air previouſly contained in water is ſet at liberty on the congelation of that fluid, and may thus partly contribute to the ſwelling of ice, and occaſion ſome of the cavities obſervable in it.

When water freezes ſlowly, its ſurface preſerves its tranſparency to ſome depth, owing to the air which is ſeparated paſſing downwards as the freezing proceeds. The air bubbles, however, ſoon begin to collect, and produce conſiderable inequalities, which increaſe as they approach the center. When, on the contrary, water is frozen with great rapidity, the bubbles of air diſperſe themſelves pretty equally through the maſs, which, in conſequence, becomes opake through its whole ſubſtance.

Reaumur obſerves that caſt iron melted, in paſſing from a fluid to its ſolid ſtate, expands. This effect is more ſenſible in this than in any other of the metals, on account of its platey texture. He found that caſt iron, thrown among ſome of the ſame metal melted, ſwims upon the top. In the caſe of immediate expanſion upon congealing, the iron ſeems to agree with water: they differ in this; the iron never expands by cold afterwards, whereas the ice, being expoſed to greater degrees of cold, becomes more bulky; the ſolid parts not being ſo cloſely connected from a particular arrangement, which renders the whole maſs lighter than before. Quickſilver contracts in becoming ſolid; and both caſt iron and ice contain ſeveral interſtices, which, if allowed for, make it appear that theſe bodies in reality occupy leſs ſpace when ſolid, than in a fluid ſtate.

CHAP. II.

HYDROSTATICS.

Diſcoveries of Archimedes in this Branch of Science.—Of the Moderns.—How Fluids are acted upon by the general Laws of Gravitation.—Particles of Fluids act independently of each other.—Experiment aſcertaining this Principle.—Fluids preſs equally in all Directions.—Cautions neceſſary in conſtructing Aqueducts, &c. to guard againſt the lateral Preſſure of Fluids.—All Parts of the ſame Fluid in Equilibrium with each other.—Surfaces of Fluids always in a Plane parallel with the Horizon.—Preſſure of Fluids in proportion to their Height.—Hydroſtatic Paradox.—Effects of Gravity on Fluids of different Denſities.—Action of Air on the Surfaces of Fluids.—The Siphon.—Action of Fluids on ſolid Bodies immerſed in them.—Why certain Bodies ſink and others ſwim in certain Fluids.—Bodies that ſwim diſplace a Bulk of Water equal to themſelves in Weight but not in Magnitude.—The ſame Body will ſink in one Fluid, which will ſwim in another.—The Hydrometer.—Fahrenheit's Hydrometer.—Recapitulation of the Doctrines reſpecting ſpecific Gravity.—How to make a Globe of Iron ſwim on the Surface of Water.—Boats made of Copper.

WATER, as a fluid, has certain properties, which, though common to all unelaſtic or incompreſſible fluids, are uſually conſidered under this topic; and indeed the ſciences of hydroſtatics and hydraulics, which regard theſe properties, immediately derive their names from that fluid *, on which the experiments, illuſtrative of them, are uſually made.

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* Ὑδωρ (Hydor) water, and στατικη (ſtatiké) the ſcience of weight. Hydraulics from ὑδωρ and αυλος (aulos) a tube or pipe.

Hydroſtatics have for their object the weight and preſſure of fluids; and in this branch of ſcience the art of determining the ſpecific gravities of bodies is uſually included, but this I have already been under a neceſſity of anticipating * in ſome degree. *Archimedes*, among the ancients, accompliſhed the moſt remarkable diſcoveries in this ſcience. He is honoured even at this day, as the inventer of the ingenious hydroſtatic proceſs, by which the purity or baſeneſs of a crown of gold was aſcertained. Among the moderns we are indebted to Gallileo, Torricelli, Deſcartes, Paſcal, Guglielmini, and Mariotte, for the beſt information on this ſubject; and by their experiments (which are as curious as they are deciſive) we are inſtructed in what we may expect or fear from the power of fluids violently acted upon by the principle of gravity, and in what manner and upon what principles we may employ, for the uſe of man, the hydraulic machines.

It has been obſerved in another place, that the propenſity which bodies have of approaching towards the earth, or perhaps towards its center, is the only cauſe of what we term weight, or gravity, and that it is by the continual efforts which they make to obey that law, that they preſs upon every obſtacle which impedes their progreſs. As fluids, like ſolid bodies, are impelled by their gravity, ſo in this caſe they preſs upon every object which oppoſes their fall; but from their nature they preſs in a different manner from ſolid bodies; hence ariſe the peculiar phenomena into which we are now to inquire.

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* See Book I. Chap. III. It was neceſſary to explain the nature of ſpecific gravity in that part of the work, both becauſe it relates rather to bodies in general than to fluid ſubſtances; and becauſe the frequent alluſions to it in the progreſs of the work would not have been otherwiſe underſtood.

Fluids are ſubſtances, the component parts of which are moveable among themſelves, having ſcarcely any coheſion one with another, and moving independently of each other. Some philoſophers * have included in this definition what they term the groſſer fluids, as, for example, a heap of corn, a heap of ſhot, of ſand, &c. as well as the rarer and more elaſtic fluids, as common air, and all other aeriform ſubſtances. The proper objects, however, of the hydroſtatic ſcience, are thoſe fluids which, in common language, are termed liquids, or thoſe which always preſent to us a plane ſurface, level or parallel to the horizon.

All liquid ſubſtances are not equally ſo; hence it follows, that the laws of hydroſtatics apply with leſs exactneſs in proportion as thoſe ſubſtances depart from perfect fluidity. Water and oil both flow when the veſſels, which contain them, are either overturned or broken; but the effuſion of oil is ſlower than that of water, becauſe the particles of oil have more coheſion among themſelves. The moſt ſingular effects in hydroſtatics princi-

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* See Briſſon, Vol. I. p. 233.

pally depend upon the extreme minuteneſs of the particles of fluids, and upon their great mobility.

To preſerve a lucid order in the conſideration of this ſubject, it will be neceſſary to divide the objects of our inquiry into three branches. In the firſt place, therefore, I ſhall conſider in what manner the principle of gravity acts on the particles of fluids, and the phenomena which it produces in the fluids themſelves; as well as their action againſt the ſides, the bottoms, and tops of the veſſels in which they are contained. Secondly, I ſhall conſider in what manner fluids of different denſities act upon each other; and thirdly, the action of fluids on bodies immerſed in them.

I. In purſuing the firſt object of this inquiry, it may be eſtabliſhed as an axiom:

1ſt, That the parts of the ſame fluid act with reſpect to their weight or preſſure, independently of each other.

This property ariſes from their having ſcarcely any coheſion among themſelves. It is otherwiſe with ſolid bodies; their ſeveral parts adhering together, they preſs in one common maſs; hence the falling of ſolid bodies is productive of a different effect from that of liquids. We dread the falling of a pound of ice upon our heads, while we are much more indifferent concerning that of a pound of water. The latter, in its deſcent, is divided by the reſiſtance of the air, by which ſome of its parts are retarded more than others; and the ſwiftneſs of the whole maſs is ſtill more retarded by this diviſion than it otherwiſe would be; for by being thus divided it acquires a larger ſurface, which abates its effect. On the contrary, a ſolid body falls upon a ſmall ſpace, which receives its whole force. Hence it follows, that angular bodies falling upon any part of the human frame are more dangerous than flat or plane ones of the ſame weight, and deſcending from the ſame height.

It follows from this principle, that if an aperture is made at the bottom of a veſſel full of any fluid, in order to prevent the flowing out of the liquor, it is only neceſſary to counteract the weight of that column of fluid which has the aperture for its baſe, and that to counteract that weight it is the ſame whether the veſſel is full of liquor, or whether it contains only a column, the baſe of which ſhall be equal to the aperture at the bottom.

Let the cylindrical veſſel of glaſs A B (plate V. fig. 1.) have a hole in the bottom at C, furniſhed with a cylindrical ferule of copper of an inch diameter D, which is to be ſtopped with a piſton G, or the ſucker of a pump well fitted to the ferule, and oiled, that it may yield to a moderate preſſure. Let the piſton be ſupported by a ſmall rod G H, faſtened at H to the ſilk which unites with the portion of the pulley M, with which the extremity of the lever M N is furniſhed, and which has for its center of motion the point L. The other portion of the pulley N, which terminates the other extremity of the lever, is alſo furniſhed with lines of ſilk, which ſupport the ſmall baſon or ſcale I. Upon the copper ferule D then fit a cylindrical tube of glaſs F E, the interior diameter of which is equal to that of the ferule, and its height equal to that of the veſſel A B. When the apparatus is diſpoſed in this manner, fill the tube E F with water, and continue to put ſmall weights into the baſon or ſcale I, until the piſton begins to riſe. Afterwards take away the glaſs tube E F, and place the piſton G in the copper ferule D, and pour water into the large veſſel A B, and it will appear that the ſame weights as before in the baſon I, will raiſe up the piſton when the larger veſſel A B is entirely full. Hence it follows that there is the ſame power to be counteracted, whether there reſts upon the piſton only a column of water of its own ſize, or whether the veſſel A B is entirely full. Such a column, therefore, preſſes upon its baſe independently of the reſt of the water contained in the veſſel.

To account for this, let us ſuppoſe all the water in a veſſel to be divided into ſeveral columns, 1, 2, 3, 4, 5, (plate V. fig. 2.) each compoſed of an equal number of parts. If the bottom of the veſſel, which ſerves for the baſe and ſupport of all the columns, is opened in *a*, the column 3, being no longer ſupported, will deſcend through the aperture, ſliding between the two columns 2 and 4, which are ſupported by the parts of the bottom of the veſſel *b* and *c*, all the moveable parts of which become (if I may uſe the expreſſion) ſmall rollers, which retard the fall only in a very ſlight degree. This effect is the reſult of the ſmall degree of coheſion between the parts of the fluid. If the columns 1 and 2 on the one part, and 4 and 5 on the other, were compoſed of parts adhering together, they would retard each other in their deſcent during their whole length, in the ſame manner as a wax candle would do; and by the fall of the column 3, a void would be made between them. But as all the particles are extremely minute, moving eaſily upon each other, they deſcend when the ſummit of the column 3 begins to deſcend, having no longer any ſupport from that ſide; and the ſuperficies of the whole maſs deſcends in the ſame manner, though only one of the columns cauſed the flow from its fall. When the parts have a degree of viſcoſity, as thoſe of oily fluids, or when the maſs of the flowing liquor has much more of breadth than of height, the void which the deſcending column leaves above it is eaſily perceived, for then the ſurface, inſtead of being plane and even, is hollow in the middle, and aſſumes a funnel-like form, becauſe the adjacent parts do not arrive with ſufficient ſwiftneſs to replace thoſe which deſcend through the aperture; beſides the preſſure of the air above the aperture is ſtronger than its reſiſtance below.

From what has been now ſtated, it is eaſy to perceive how fluids differ from ſolids in the phenomena of gravitation. If the veſſel A B (plate V. fig. 1.) being full of water, and the tube E F being removed, it was required to raiſe up the piſton G; all that is neceſſary in this caſe is, to ſupport the weight of the column of water directly above the piſton, becauſe this column can move independently of the remainder; but if the whole maſs of water was converted into ice, then the maſs ceaſing to be a liquid, and all its parts adhering together, to raiſe up the piſton it would be neceſſary to ſupport the weight of the whole maſs.

2dly, Fluids preſs equally in all directions.

In other words, they not only preſs from the top to the bottom like other bodies, but they alſo preſs, according to their weight, upon all bodies that oppoſe them in a lateral direction, and even from the bottom to the top. Hence, if a caſk is filled with liquid oil, the oil will run out if an aperture is made in the ſide, but when it is congealed it will not run out, on account of its having become a ſolid body, for ſolid bodies preſs only from their vertex to their baſe, and not laterally.

To underſtand properly this lateral preſſure of fluids, and alſo that which they exert from their baſe towards their vertex, it is neceſſary to conſider them as a maſs of ſmall globules depoſited in a veſſel; and to remember that theſe minute globules are not arranged regularly as upon a cord, but that very frequently one column exerciſes its preſſure between two others, and has a propenſity to diſplace them, as may be ſeen in plate V. (fig. 3.) where the perpendicular preſſure which is made oppoſite to the point *d*, is directed by the lateral columns towards the ſides, *e f*, of the veſſel, in ſuch a manner, that if the veſſel was open in thoſe places the liquid would flow out, on account of the great mobility of its parts. It is by the ſame mode of reaſoning that the preſſure of fluids, from their baſe towards their vertex, is accounted for: for example, when the column *d f* (fig. 3.) has a tendency to diſplace the two particles *g h*, the particle *g* cannot move any farther becauſe it is impeded by the ſide of the veſſel; but the particle *h* may be raiſed from the baſe towards the top, unleſs a column equal to the column *i k*, or ſomething equivalent, preſſes upon it to prevent it.

It is upon this principle that the water, elevated by the New River water-works, after having deſcended from a baſon in a vertical pipe, and then after having flowed horizontally in a ſucceſſion of pipes under the pavement, is raiſed up again, through another pipe, as high as the fountain at the Temple Garden. It is alſo upon this principle that a veſſel may be filled either at the mouth or at the bottom indifferently, provided that it is done through a pipe, the top of which is as high as the top of the veſſel to be filled. Hence it follows, that when piers, aqueducts, reſervoirs, or other hydraulic works for the retention of water are to be conſtructed, it becomes neceſſary to proportion their ſtrength to the lateral preſſure which they are likely to ſuſtain, which becomes greater as the height of the water is more conſiderable. Nearly the ſame precautions are neceſſary to be taken with reſpect to what ſome philoſophers call the groſſer fluids, which alſo have a propenſity to expand, as well on account of the ſmallneſs of their parts as from the ſmall degree of coheſion which exiſts between them. Walls deſigned to ſupport terraſſes ought to be ſufficiently ſtrong to reſiſt the lateral preſſure of the earth and rubbiſh which they are to ſuſtain, as this preſſure will be greater as the particles of earth, and of the other materials of which the terraſſes are compoſed, are leſs bound together, and in proportion as the terraſſes are more elevated.

3dly, All the parts of the ſame fluid are in equilibrium with each other, whether they are contained in one veſſel or many, provided they communicate with each other; and their ſurfaces alſo are always in a plane parallel to the horizon.

This is a conſequence of the principle which has been before eſtabliſhed: for, ſince the particle *b* (fig. 3.) would be raiſed from the baſe towards the top, unleſs a column equal to the column *i k*, preſſed upon it to retain it in its place; it follows that to be in equilibrium, the upper extremities of the two columns ſhould be in the ſame horizontal plane, or in points equally diſtant from the center of the earth; which points, however, cannot be found by a right line; for in the diſtance of a thouſand fathoms there is about one foot difference in the perpendicular height. From this property of fluids it follows, that water conducted by pipes placed in the earth, will remount as high as the place whence it flowed, whatever the depth under ground through which it may have been conducted by pipes. It is cuſtomary to allow half an inch of inclination in the length of ſix feet, to counteract the reſiſtance produced by friction; but it is clear, from what has been ſaid, that this is not abſolutely neceſſary, for however long the paſſage might be, the water would ſtill aſcend as high as the place whence it came, but it would require a little longer time to accompliſh the aſcent. We are enabled, upon this principle, to account for the ſprings which are ſometimes found on the tops of mountains. Such waters flow from mountains ſtill more elevated (whether they are far or near) by ſubterraneous canals. It follows from this principle, that if there are many reſervoirs which communicate together, it is neceſſary only to ſee one of them to know the height of the water in the others; for it muſt neceſſarily be of the ſame height there as in all the reſt.

From what has been obſerved, viz. that when all the parts of the ſame fluid are in equilibrium, their ſurfaces will alſo be in a plane parallel to the horizon, or, in other words, every part of the ſurface at an equal diſtance from the center of the earth, it follows, that when the ſurface of water is very large, it becomes neceſſarily and ſenſibly convex. This is eaſily perceived at ſea, where the maſts of ſhips are obſerved at a diſtance before any other part of the ſhip can be diſtinguiſhed.

4thly, Fluids preſs as well perpendicularly as laterally, not, however, in proportion to their quantity, but in proportion to their height above the plane of the horizon.

For example, if ſeveral veſſels of the ſame height and baſe are filled with water, all their bottoms will bear the ſame degree of preſſure, whatever may be the form and ſize of the veſſels in other reſpects. Suppoſe three veſſels to be filled with water, A B C D (fig. 4.) E F G H (fig. 5.) L M N O P Q (fig. 6.) whoſe heights A B, I F, L T are equal, and alſo ſupported by equal baſes B C, F G, N O;

N O; it will be found, by experiment, that all the bottoms of theſe veſſels will be equally preſſed, though the quantities of water which they contain may be very different. In the veſſel (fig. 4.) the bottom B C is preſſed by the whole maſs of water A B C D, becauſe the fluid, in this caſe, preſſes in the ſame manner as a ſolid body; let us ſuppoſe the weight of the water to be ſix pounds: In the veſſel (fig. 5.) it is eaſy to conceive, from what has been ſaid before, that the bottom F G is alſo only preſſed by ſix pounds, though the veſſel is evidently much larger than the firſt; becauſe the bottom F G ſupports only the column I F G K, equal to that of the veſſel (fig. 4.) and this column exerciſes its preſſure independently of the reſidue of the water in the veſſel, which is ſupported by the ſides, E F, H G, of the veſſel (fig. 5.) But the principal difficulty conſiſts in comprehending how the bottom of the veſſel N O is ſtill preſſed by a weight of ſix pounds, although one pound of water would be ſufficient to fill the veſſel. It is accounted for in this manner; it is certain that upon the portion T V of the bottom N O, there is a preſſure equal to that of a column of water of which T V is the baſe, and L T the height. If, upon every other ſimilar portion of the ſame bottom, there is a preſſure equal to that of the column L T V Q, the bottom is equally preſſed upon all its parts. For inſtance, there is a preſſure upon the portion V X equal to that of a column of water Q V X R, which is itſelf equal to the column L T V Q; for the ſmall column of water P V X S, which reſts above, has a propenſity to be elevated by the preſſure of the adjacent column L T V Q, and with a force equal to the exceſs L M P Q of this great column over the ſmall one; therefore the upper part, P S, is preſſed by the ſame power; but the re-action is equal to the preſſure. The part P S re-acts with a force equal to the exceſs L M P Q of the great column over the ſmall one. There is, therefore, a preſſure upon the portion V X of the bottom N O, from the ſmall column of water P V X S, and from the re-action of the part P S, equal to the preſſure of a column of water, Q P S R, both of which added together are equal to the preſſure of the column L T V Q. What has been ſaid of the portion V X may be ſaid of all the reſt. Hence it follows that the bottom of the veſſel (fig. 6.) is every where equally preſſed.

There is a maxim deduced from what has been ſtated, which is termed by philoſophers the hydroſtatic paradox; it is nevertheleſs founded upon the ſureſt baſis of truth, and has a conſiderable influence in almoſt all hydraulic engines, viz. "that a given quantity of water may exert a force two or three hundred times leſs or greater, according to the manner in which it is employed." If, for inſtance, the ſame quantity of water as the veſſel (fig. 5.) will contain, is poured into a veſſel reſembling that of (fig. 6.) but high enough to contain it, the preſſure upon the bottom N O will be conſiderably greater than that upon the bottom F G.

One of the moſt uſeful machines to ſhew that a ſmall quantity of water is capable of great preſſure, is

Fig. 1.

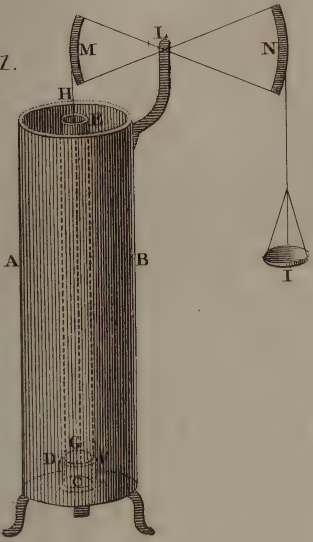


Fig. 2.

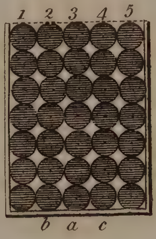


Fig. 3.

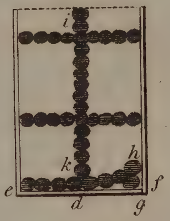


Fig. 4.

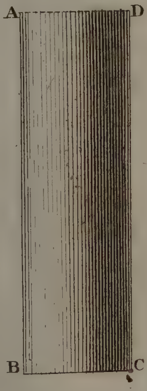


Fig. 5.

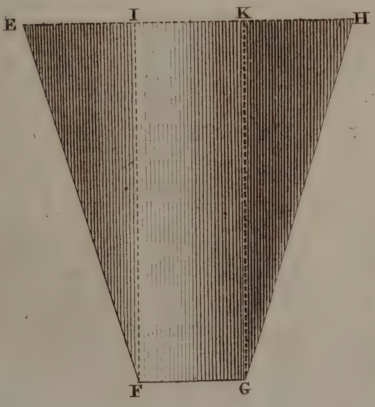
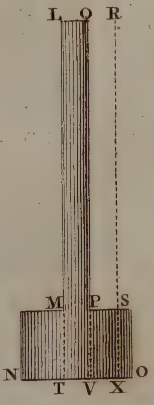


Fig. 6.



is the hydroſtatic bellows. This machine (Plate VI. fig. 1.) conſiſts of two thick oval boards, each about three feet broad, and four feet long, united to each other by leather, like a pair of common bellows, or a barber's puff. Into the lower board a pipe B, ſeveral feet high is fixed at *e*. Now, in ſhewing experiments with this ſimple machine, which even the reader himſelf might eaſily make, let water be poured into the pipe at its top C, which will run into the bellows, and ſeparate the boards a little: then to ſhew how much a little water will be able to effect by preſſure, let three weights, each of an hundred pounds, be laid upon the upper board. Now if we pour more water into the pipe, it will as before run into the bellows, and raiſe up the board with all the weights upon it. And though the water in the tube ſhould weigh in all but a ſingle pound, yet the preſſure of this ſmall force upon the water below in the bellows, ſhall ſupport the weights, which are three hundred pounds; nor will they have weight enough to make them deſcend, and conquer the weight of the water, by forcing it out of the mouth of the pipe.

It is clear from theſe principles, that the tun T O (fig. 2.) filled with water, may be burſt by preſſing it with ſome pounds additional weight of the fluid, through the tube A B, which may be ſuppoſed to be from twenty-five to thirty feet in height. From what has been ſaid of the veſſel (fig. 6.) it indeed neceſſarily follows, that the ſmall quantity of water which the tube A B contains, preſſes upon the bottom of the tun as much as if a column of water had been added as wide as the tun itſelf, and as long as the tube, which would evidently be an enormous weight.

II. The effects of gravity on fluids of different denſities will, from what has preceded, not be very difficult to comprehend.

It has been obſerved, that fluids are maſſes of ſmall bodies moveable with great facility among themſelves independently of each other, preſſing ſeparately and in proportion to their maſſes.

It is proved alſo by chemical analyſis, that even theſe minute particles are compoſed of particles ſtill ſmaller. Now whether it reſults from the interpoſition of caloric (or the matter of fire) in greater or leſs quantities, which we know is the cauſe of all fluidity, and alſo of the difference that exiſts between the incompreſſible and elaſtic fluids; or whether it may depend upon the ſhape or ſize of the particles, which, as in ſolid bodies, may increaſe or diminiſh the poroſity, it is certain, that there is a conſiderable difference with reſpect to denſity in different fluids.

From this difference in point of denſity, a ſeparation may be obſerved generally to take place, ſoon after mixing two heterogeneous fluids together, unleſs this effect is counteracted by ſome more powerful cauſe. It has been obſerved, that the particles, according to their weight, preſs independently of each other. Thoſe therefore which have the moſt denſity, having more power to gain poſſeſſion of the lower part of the veſſel which contains them, oblige the others to yield and reſign their ſituation; and hence a ſeparation is effected. When oil and water, for inſtance, have been well ſhaken together, and afterwards the whole left in a ſtate of reſt, the water, having more denſity than the oil, takes the lower poſition and the oil riſes to the ſurface. If this effect does not take place, it is owing to the intervention of one of the following cauſes. Firſt, a kind of elective attraction, which may exiſt between the particles of different fluids, as when water and wine are mixed together, the water, though heavier than the wine, does not ſeparate itſelf. Secondly, the viſcoſity of one of the ſubſtances, as when the whites of eggs are beaten together, and by that means a conſiderable quantity of air mixes with them; the air, though much lighter, has not power to diſengage itſelf from the matter in which it is enveloped, in order to effect its eſcape.

If two fluids of different denſities are placed in a ſtate of equipoiſe with each other, and have the ſame baſe, their perpendicular heights above the horizon will be in a reciprocal ratio to their denſities or ſpecific gravities.

If, for example, mercury is put into an inverted ſiphon, and water is poured into one of the branches, in order to elevate the mercury in the other branch one inch above its level, it is neceſſary that the water ſhould be about thirteen inches and an half high. The height of the water then will be thirteen times and a half of that of the mercury; becauſe the ſpecific gravity of mercury is about thirteen times and a half as great as that of water.

This obſervation will alſo apply to the reciprocal action of air and water, or air and mercury upon each other, as was evinced in a former book, when treating of the Torricellian experiment and the barometer *. Many of the phenomena, indeed, of hydroſtatics and hydraulics are to be referred to the preſſure of the atmoſphere, and for this reaſon, the preſent ſubject has been in part anticipated, when it was neceſſary to treat of air as a fluid.

It is, however, proper on the preſent occaſion, to recal to the reader's attention ſome of the properties of this fluid, and he will eaſily remember, that as a fluid, air is poſſeſſed of gravity, and conſequently preſſes upon all bodies which oppoſe it; and it is neceſſary to add, that like water, it preſſes in all directions. Its perpendicular preſſure has been already ſufficiently proved; and its lateral preſſure may alſo be eaſily demonſtrated. If a ſmall hole is made with a gimblet, either in the ſide or bottom of a caſk or veſſel which is quite full of liquor, it will not run out, becauſe the external air which preſſes againſt the hole, ſuſtains the liquor, which has not a ſufficient height to overcome its preſſure. Hence the neceſſity of a vent-peg, to enable liquor to be drawn out of a full caſk. The elaſticity of the ſmall quantity of air which is introduced at the vent preſſes the fluid, and overcomes the preſſure of the air at the cock. There is an

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* See Book v. Chap. 9.

inſtrument in common uſe, called a Valencia, for extracting ſmall quantities of liquor out of the bung-holes of caſks. It is a tube with a ſmall aperture at the bottom and the top. When full, if the hole at the top is ſtopped with the thumb or finger, ſo as to prevent the preſſure of the air at the top, the liquor will not run out of the hole at the bottom, being kept in by the force of the external air.

It is proper to obſerve, that all the effects which depend upon the preſſure of air, take place in a room where the column of air is terminated by the ceiling, as well as without doors where the column of air has the whole height of the atmoſphere; and the reaſon is, becauſe the air in the room has a communication with that on the outſide, ſuppoſing it to be only by means of the key-hole. Thus a barometer placed in a hall, will have its mercury as high as if it was placed in an open field.

The curious effects produced by ſiphons, all depend upon the preſſure of the air.

A ſiphon is a bent tube A B C (fig. 3), made of glaſs, of metal, or of wood. One branch of which A B, is ſhorter than the other B C. In order to make uſe of this inſtrument, place the extremity of the ſhort branch A B in the veſſel E E, (fig. 4.) which may be ſuppoſed to contain any fluid matter, as water for inſtance. If the air then is drawn by ſuction* out of the ſiphon at the extremity C of the long

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* Suction is here evidently uſed in the popular ſenſe of the word, to imply that action of the mouth which extracts the air from a given ſpace: for in ſtrict philoſophical language there is no ſuch thing.

branch

branch B C, the liquor will begin to flow, and will not ceaſe while the ſhort branch A B remains immerſed in the fluid. It is eaſy to ſee that the preſſure of the air upon the ſurface of the fluid in the veſſel, is the cauſe of its diſcharge through the ſiphon. For ſuppoſe G F the confines of the atmoſphere, all the points of the ſurface A of the liquor will be equally preſſed by the column of air A F; if, therefore, at ſome point of this ſurface, the preſſure is ſuſpended, the liquor muſt flow at that point, becauſe it finds leſs reſiſtance there than in any other part; this is therefore the obvious reaſon why the ſiphon becomes full immediately after the air is drawn out at the extremity C.

If the two branches of the ſiphon were of equal lengths, as B A, B D, the flow through the bent tube would not take place; becauſe the column of air D G which would reſiſt in D, being of an equal height with that which preſſes at A, would alſo be in equilibrium with it, in the ſame manner as the two columns of the fluid B A, B D. But ſince B C, one of the legs, is longer than the other, though the column of air G C, which anſwers to it, is really longer than that which preſſes in A; yet it is not capable of preventing the paſſage of the fluid. To underſtand this more perfectly, let us conſider the column of air G C to be divided into two parts, one of which, G D, would form an equipoiſe with the column of air F A, and would be capable of ſtopping the flow from the tube if the branch B C ended in D. The portion of fluid which fills the part D C of the ſiphon, will find no other reſiſtance in C than

C than one column of air D C of the ſame length with it, which is evidently very inferior to it in weight. This portion of fluid then flows out, becauſe it greatly exceeds in weight the column of air which is oppoſed to it. But while it continues to flow, nothing ſuſtains that which is above it, which flows neceſſarily, while the preſſure of the air at A furniſhes a new ſupply of fluid to replace that which runs out. It is by theſe means, that the water in the ſiphon continues to flow without intermiſſion; becauſe the reſiſtance of the air in C is as much exceeded, as the length of the branch B C of the ſiphon exceeds that of the branch A B. In order to prove this, ſuppoſe there is added at C a tube to lengthen that branch, then it will plainly appear, that in a given time more water will flow than would have been diſcharged without that augmentation to the branch B C.

Since it is the preſſure of the air which elevates the fluid in the ſhort branch B A, it follows, that the height of this branch is limited to thirty-two feet when the fluid is water, becauſe the preſſure of the atmoſphere cannot elevate water higher; but when the liquor is mercury, the height of the ſhort branch ſhould not exceed thirty inches, becauſe the atmoſphere cannot ſuſtain mercury at a greater height.

III. The action of fluids on ſolid bodies immerſed in them, has been already in part anticipated, in treating of ſpecific gravity. It is neceſſary, however, to reſume that ſubject to a certain extent in this place, and I ſhall endeavour as much as poſſible to avoid repetition.

It is evident, that when a ſolid body is plunged into a fluid, it occupies a ſpace in that fluid exactly equal to its own magnitude. The quantity of fluid then ſo diſplaced, either equals in denſity and conſequently in weight, the ſolid which diſplaced it; or, on the contrary, one of the two muſt weigh more than the other. In the laſt caſe, which is moſt common, the quantity by which the heavier body ſurpaſſes the lighter, is called the ſpecific weight or gravity.

It has been obſerved before, that fluids exerciſe their preſſure in all directions, conſequently a ſolid body plunged into a fluid is preſſed at all points. It has alſo been proved, that this preſſure increaſes in proportion to the height of the fluid; the preſſure, therefore, which the body undergoes, is greater in proportion to the depth into which it is plunged. Laſtly, it has been proved, that when two fluids are placed in equipoiſe, their reſpective heights are in proportion to their denſities; and therefore bodies plunged to an equal depth, are compreſſed according to the denſity of the reſpective fluid.

If a body is heavier than the fluid in which it is immerſed, it is evident that it will ſink to the bottom, by its ſpecific gravity. If a body is lighter than the ſame bulk of the fluid into which it is plunged, a part of it will ſwim, and the remaining part which is immerſed diſplaces a quantity of fluid which weighs exactly as much as the whole of the ſolid body*.

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* ‘From what I have already explained, you muſt neceſſarily have diſcovered the rationale of *ſinking* and *ſwimming*. You ſaw that when a body was bulk for bulk heavier than the fluid, by being immerſed it loſes only the weight of an equal bulk of the fluid, and conſequently the *reſidual* or remaining gravity of the ſolid muſt carry it down to the bottom, or make it *ſink*.

On the other hand, if the ſolid has leſs weight in the ſame bulk than the fluid, then it cannot by its weight diſplace or raiſe upwards its whole bulk of the fluid, but only ſo much of it as is equal to its own weight, and from this deficiency in weight it will be only partly immerſed, and will therefore *ſwim* upon the upper part of the fluid.

Of all the animals, however, thrown into the water, man is the moſt helpleſs; the brute creation receive the art of ſwimming from nature, while man can only acquire it by practice; the one eſcapes without danger, the other ſinks to the bottom. Some have aſſerted, that this ariſes from the different ſenſibilities each have of the danger; the brute, unterrified at his ſituation, ſtruggles, while his very fears ſink the lord of the creation.

But much better reaſons may be aſſigned for this impotence of man in water, when compared to other animals; and one is, that he has actually more ſpecific gravity, or contains more matter within the ſame ſurface than any other animal. The trunk of the body in other animals is large, and their extremities proportionably ſmall; in man it is the reverſe, his extremities are very large in proportion to his trunk. The ſpecific weight of the extremities is proportionably greater than that of the trunk in all animals, and therefore man muſt have the greateſt weight in water, ſince his extremities are the largeſt.

Beſides this, other animals to ſwim have only to walk (as it were) forwards upon the water; the motion they give their limbs in ſwimming is exactly the ſame they uſe upon land; but it is different with man, who makes uſe of thoſe limbs to help him forwards upon water, which he employs to a very different purpoſe upon land.’ ADAMS’s *Lectures*, Vol. iii. p. 408.

If, for inſtance, water is poured into a glaſs veſſel (fig. 5.) furniſhed with a ſmall cock near the bottom; if the height of the water in the veſſel is marked with a ſmall bandage of thread or paper; and, laſtly, if a ball of wood is thrown into it, it will appear that part of the wood will be immerſed, and part of it remain above the water, and that the immerſed part will raiſe the water in the veſſel juſt as much as if a volume of water had been added equal to the ſolid contents of the part under water.

If a quantity of water is then let out of the veſſel by means of the ſmall cock, until the ſurface is reduced as low as the mark which pointed out its height at the beginning of the proceſs, it is clear, that the water drawn out in this manner will be equal in its ſolid contents to thoſe of the immerſed part of the wooden ball; and alſo, if this volume of water is weighed, it will be found to be of exactly the ſame weight as the whole ball of wood.

Hence it follows, that a boat upon a river diſplaces a quantity of water exactly of the ſame weight with the boat and its lading; and if more weight is added, it will ſink deeper in the water in the ſame proportion; and the immerſed part is more or leſs in extent, according to the denſity of the water. Hence, as water when impregnated with ſalt, is heavier and denſer than pure water, as was formerly proved*; it follows, that the ſame boat and lading will *draw* leſs water (according to the ſeaman's phraſe) in the ocean, than in a river of

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* Book vi. chap. 7.

freſh

Fig. 1.

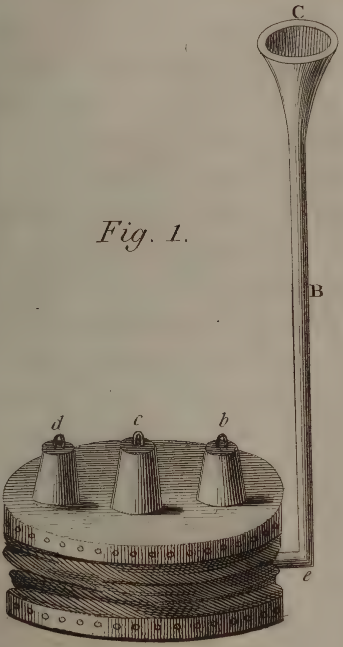


Fig. 2.

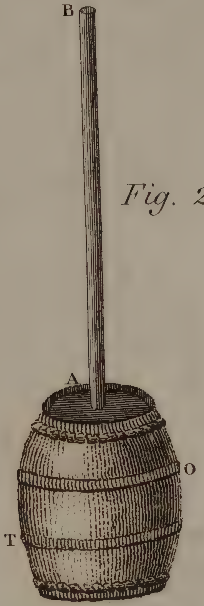


Fig. 3.

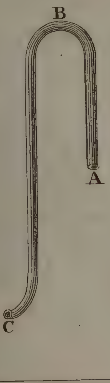


Fig. 4.

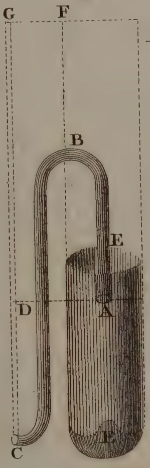
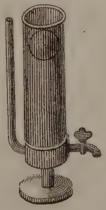


Fig. 5.



If, therefore, the weight of the hydrometer is ſuch, that it will ſink in water as far as E, it will ſink ſtill deeper in lighter fluids; it will ſink for inſtance in wine as far as F; in ſpirits of wine as far as G, &c. But if it is plunged into liquors heavier than water, it will not ſink ſo far as E; for example, in beer it will only ſink to D, and always as much leſs as the liquor into which it is plunged is denſer and conſequently heavier.

By this proceſs it will be eaſily diſcovered, whether one kind of fluid is lighter than another with which it is compared; but the proportion cannot be accurately determined; for in order to that, it would be neceſſary to know exactly the proportion between the tube A C and the balls B and S; which is impoſſible according to the above mode of conſtructing the inſtrument; and it would alſo be further neceſſary that the tube A C ſhould be perfectly cylindrical, which never is the caſe. The moſt certain mode of acquiring this exact knowledge is, to operate always with equal volumes of fluids: and for this purpoſe, it is neceſſary to make uſe of Farenheit's hydrometer.

This inſtrument (fig. 2.) is compoſed of a ſmall oval glaſs bulb or bottle B; the neck of which A C is very ſmall, and terminates with a baſon D E, deſigned to receive ſmall weights.

The inſtrument is ballaſted by means of a ſmall ball of glaſs S fixed underneath it, in which there is depoſited ſome quickſilver. A ſmall grain of ſmalt (*a*) is fixed upon the neck, and the inſtrument is then complete.

In order to make uſe of this hydrometer, it is neceſſary to begin by knowing its exact weight, which ſhould be marked upon it, to prevent its being forgotten. The inſtrument is then plunged into diſtilled water; and by putting weights into the baſon D E, it is made to ſink as far as the grain of ſmalt (*a*). The weights which were made uſe of to produce this immerſion, added to the weight of the hydrometer, gives exactly the weight of the volume of water meaſured by the inſtrument. By repeating the ſame operation upon any other fluid, the weight of the volume of that fluid meaſured by the hydrometer, may be known with equal exactneſs. Hence it follows, that the quantity of theſe two volumes are equal, becauſe they are meaſured by the ſame inſtrument: the difference of their weight then will give the difference of their ſpecific gravity, or the relation between their denſities. To determine this relation exactly, the following proportion muſt be obſerved: The ſpecific gravity of the proved liquor, is to that of diſtilled water as the weight of a volume of that fluid meaſured by the hydrometer, is to the weight of the volume of water alſo meaſured by it. If the ſpecific gravity of the one is known exactly, the ſpecific gravity of the other may be determined by it, and alſo that of all other fluids which are proved in the ſame manner.

The whole of what has been advanced in this chapter, and in that of the firſt book upon ſpecific gravity, may be briefly ſummed up in the following propoſitions: Firſt, when two bodies are equal in their magnitude, bulk, or volume, their ſpecific gravities are to each other as their denſities. So that one body has twice the ſpecific gravity of another, when it has twice the denſity of that other body comprized in the ſame ſpace or magnitude.

Secondly, when two bodies loſe an equal weight in the ſame fluid, they have the ſame magnitude or ſolid contents, whatever form they may aſſume, ſince they each loſe a weight equal to the bulk or volume of fluid which they diſplace.

Thirdly, the ſpecific gravity of bodies is inverſely as their bulk when their weights are equal. As one body has twice the ſpecific gravity of another, when with the ſame weight, it has only half the magnitude of that other body.

Fourthly, the ſpecific gravities of two bodies are in a direct proportion to their denſities, and in an inverſe proportion to their magnitudes. This propoſition is a neceſſary conſequence of two preceding, viz. of the firſt and third.

Fifthly, the ſame body will loſe a greater quantity of its weight in a fluid ſpecifically heavier than in a lighter one; becauſe it will always loſe a portion of its weight equal to the weight of that bulk of fluid which it diſplaces. It requires then a greater force to ſuſtain it in a lighter than in a heavier fluid: it will require more force to ſuſtain it in air than in water.

Sixthly, the ſpecific gravities of bodies of an equal weight (when weighed in a common balance) are proportionate to the weight which they loſe in the ſame fluid. So that of two bodies of equal weight, if the one loſes one-fifth and the other two-fifths of its weight in the ſame fluid, the ſpecific gravity of the firſt is to that of the ſecond as two to one.

Seventhly, if a body is of the ſame ſpecific gravity as a fluid, when immerſed in that fluid it will be in equilibrium with it, and remain at any depth at which it is placed.

Eighthly, if a body ſpecifically lighter than a fluid is plunged entirely into it, and then left to itſelf, it will remount with a force equal to the exceſs of weight which a volume of that fluid poſſeſſes above an equal bulk of the body immerſed.

Ninthly, the ſpecific gravity of a ſolid is to that of a fluid heavier than itſelf, and upon which it will ſwim, as the bulk of the immerſed part is to the bulk of the whole body. So that if the magnitude or bulk of the immerſed part is to the magnitude of the whole body as two to three, the ſpecific gravity of the ſolid is to that of the fluid as two is to three.

Tenthly, the weight and the magnitude of a body, and alſo the weight of a fluid ſpecifically heavier than the body, being given, ſuppoſe it is required to find the force requiſite to keep that body entirely immerſed in the fluid. As this force is equal to the ſpecific weight of the fluid, find, by means of the given bulk of the ſolid, and the known weight of a cubic foot of the fluid, by the rule of three, the weight of a bulk of the fluid equal to the bulk of the ſolid. Subſtract from this weight, the weight of the ſolid, and the remainder will be the force required. For example, ſuppoſe it was required to find the force neceſſary to retain under water a ſolid of eight cubic feet in contents, and of four hundred pounds weight. Since a cubic foot of water weighs about ſeventy pounds, the weight of eight cubic feet of water is five hundred and ſixty pounds; then if four hundred pounds are ſubſtracted; the one hundred and ſixty remainder; is the force neceſſary to keep the ſolid immerſed in the water, and to prevent it from riſing to the ſurface.

Eleventhly, the weight of a body ſpecifically heavier than a fluid, and the weight of that fluid ſpecifically lighter, being given, ſuppoſe it is required to determine the cavity which that body ſhould have, in order that it may ſwim upon the fluid.

The weight of a cubic foot of the fluid being given, the bulk of the portion of the fluid equal in weight to that of the body, is found by the rule of three. If then the cavity of the body is made ſo, that the bulk may be a little larger than the magnitude already found, the body will have leſs weight under the ſame magnitude than the fluid. For example, ſuppoſe that it is required to make a ball of iron of thirty pounds, and of ſuch a magnitude as that it will ſwim upon water. Since the weight of a cubic foot of water is ſeventy pounds, a volume of water weighing thirty pounds will be three-ſevenths of a cubic foot: hence it will be eaſy to find what the diameter of a ſphere muſt be, the ſolid contents of which ſhall be three-ſevenths of a cubic foot. Therefore, the ball of iron muſt be made hollow within, and in ſuch a manner that its diameter may be greater than the diameter of a ſphere, the ſolid contents of which is three-ſevenths of a cubic foot: if this ball is made eleven inches three lines in diameter, it will ſwim. Hence we ſee that it is not neceſſary for a body to ſwim, that it ſhould be compoſed of matter ſpecifically lighter than water; it ſuffices that its bulk or volume ſhould be great and its gravity ſmall: for though copper is about eight times as heavy as water, yet military men have occaſionally employed boats of copper in conſtructing bridges for the paſſage of troops.

A copious table of ſpecific gravities is given in the appendix to this volume.

Chap. III.

HYDRAULICS*.

Of the Diſcharge of Fluids through ſmall Apertures.—The Diſcharge of Fluids through ſucceſſive Pipes.—Artificial Fountains.—Pumps.—The Raiſing Pump.—The Forcing Pump.—The Sucking Pump.—The Compound Pump.—The Fire Engine.—Motion of Water in Conduit Pipes.—Oſcillatory Motion of Water in a Siphon.—Oſcillatory Motion of Waves.—Motion of Wheels acted upon by Water; and Conſtruction of Water Mills.

THE ſcience which has for its object the motion of fluids is called hydraulics; and its immediate application is to furniſh us with the means of conducting water from one ſituation to another, by canals or aqueducts, and to elevate it by pumps, jets-deaux, and other hydraulic engines, either for the purpoſes of ornament or uſe.

In treating of this ſubject I ſhall commence with the ſimpleſt principles, and ſhall firſt ſpeak of the diſcharge of fluids through ſmall apertures.

When water flows from a veſſel which has a hole or aperture in the bottom, ſmall in compariſon to the width of the veſſel, the water deſcends vertically, and the ſurface appears ſmooth, but at three or four inches from the bottom the particles turn from this direction, and proceed on all ſides with a motion more or leſs oblique towards the aperture. The ſame effect takes place when water flows through an aperture laterally. The tendency of the particles towards the aperture is a neceſſary conſequence of their perfect mobility; for they will certainly be directed towards the point where there is the leaſt reſiſtance, and that point is the aperture.

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* Almoſt the whole of this chapter, and great part of the preceding, are tranſlated from the firſt volume of Briſſon's "Traite Elementaire de Phyſique," Chap. VIII.

It is alſo to be obſerved, that in this caſe, at a ſmall diſtance from the bottom, a kind of funnel is formed in the water, the point of which correſponds to the center of the aperture; when, however, the water flows through a lateral orifice or aperture, there is formed only a kind of half funnel, which does not appear to commence till the ſurface is near touching the upper ſide of the hole. It is probable that the funnel begins to form itſelf from the firſt moment of the flow; but it does not become perceptible till the ſurface is only at a ſmall diſtance from the bottom.

It appears alſo, that the funnel commences higher or lower, according to the width of the bottom; and that the formation of it is leſs prompt or leſs perceptible, according to the proportion of the aperture to the extent of the bottom. The funnel is alſo augmented by any roughneſs which may exiſt at the ſides or bottom of the veſſel.

Water flows out of a ſmall hole in the bottom of a veſſel with a velocity equal to that which a ponderous body acquires in falling from a height equal to the vertical height of the ſurface of the fluid above the aperture.

The ſame law takes place in a lateral orifice; for the preſſure of the fluid is equal (at the ſame depth) in all directions, and conſequently produces the ſame degree of velocity.

A fluid, in running out of an aperture, acquires a velocity ſufficient to make it remount to a vertical height equal to that of the ſurface of the fluid above the aperture, in the ſame manner as a falling body acquires a velocity capable of making it aſcend to the height from which it deſcended.

It is evident, from the theory of falling bodies, that if the velocity of the fluid in running through the aperture was uniformly continued, the fluid would move through a ſpace double the height of the fluid above the aperture in the ſame time that a falling body would employ in deſcending from that height.

The height being the ſame, the velocity of the fluid in running out of the orifice will always be the ſame, whatever the ſpecies of the fluid may be, and whatever its denſity. It is true, that when the fluid has more denſity it preſſes more forcibly, but then the maſs is more conſiderable, and it is evident, that when the moving powers are proportioned to the maſſes which they put in motion, the velocities are equal.

The quantities of a fluid diſcharged in the ſame ſpace of time through different orifices, ſuppoſing the veſſels equally full during the whole of the experiment, are to each other as the products of the areas of the apertures by the ſquare roots of the heights. For inſtance, it has been proved by experiment, that a circular orifice of an inch diameter, made in a thin veſſel or partition, and under a ſurface of fluid four feet in height, will furniſh, in one minute of time, five thouſand four hundred and thirty-ſix cubic inches French.

If, therefore, it was an object to aſcertain how much a circular orifice of two inches diameter, under nine feet of height from the ſurface of the water, would furniſh in the ſame time, the following proportion muſt be employed (it muſt be obſerved, that the orifice of two inches is four times as great as an orifice of one inch, becauſe the areas of circles are as the ſquares of their diameters):

$$1 \times \sqrt{4} : 4 \times \sqrt{9} :: 5436 : x$$

Or at length

$$2 : 12 :: 5436 : 32616$$

$$\begin{array}{r} 12 \\ \hline 2)653232 \\ \hline \end{array}$$

Therefore 32616 cubic inches of water will flow from an aperture of two inches in diameter in one minute, the orifice being made nine inches from the ſurface, which is ſuppoſed to be kept at that height the whole time.

If a veſſel of a priſmatic form is filled with water, and permitted to empty itſelf entirely through an orifice at the bottom, and the time that it conſumes in emptying itſelf is obſerved; and if afterwards, having repleniſhed the veſſel, the water is made to flow through the ſame aperture, the veſſel being kept full the whole time, there will run out in this ſecond inſtance, during the ſame time that the veſſel took to empty itſelf at firſt, a quantity of water double that which runs out in the firſt caſe, for the abſtraction of the water produces a kind of funnel, which in this laſt caſe does not take place.

We often perceive water flow through lateral apertures, which, though ſmall in compariſon to the width of the reſervoirs, cannot be regarded as having all their points at an equal diſtance from the ſurface of the fluid; ſuch, for example, as the apertures through which water ſometimes flows in mills. The common method of determining the quantity diſcharged is as follows: ſuppoſe, in the firſt place, the aperture to be ſtopped up by a plate of metal, which is perforated with a number of holes; if each of theſe holes is regarded as particular and inſulated, the rapidity of the flow through each will be according to the correſpondent height of the fluid; then if the number of holes are multiplied *ad infinitum*, or, which will amount to the ſame thing, if the plate is ſuppoſed to be entirely taken away, the velocity at each point of the ſuppoſed orifice will be according to the correſpondent height of the fluid; and in eſtimating the quantity of water diſcharged, ſome attention muſt be paid to the inequality of the motion; yet it muſt not be aſſerted that this reaſoning is entirely concluſive. In proportion as the ſum of the ſmall holes made in the plate is ſmall in compariſon with the ſize of the reſervoir, the portions of water which flow through each hole are forced out by the abſolute weight of the column above; but the moment that the number of apertures augment *ad infinitum*, and the ſtreams of water which run through them become contiguous, it cannot be clearly ſaid that the liquid flows in the ſame manner as through ſmall inſulated holes; yet as this hypotheſis gives a reſult ſufficiently conformable to experiments, it may be uſeful to preſerve it, and the more ſo, as it leads to very ſimple calculations, and in all common queſtions this ſimplicity may be preferable to the minuteneſs of fractional operations.

The quantity of water which iſſues from theſe apertures in a given time is not ſo great as their ſize might at firſt ſuggeſt, becauſe the ſtream is contracted by running out of each orifice, and that contraction extends to a diſtance nearly equal to half the diameter of the aperture; and the diameter of the contracted ſtream is to the diameter of the aperture a little more than as three to four, or as three and one-ſixth to four, or nineteen to twenty-four; ſo that its area is to that of the aperture as ten to ſixteen. It is nearly the ſame when water flows through lateral apertures. The contraction of the

ſtream

ſtream is a proof of what has been before ſtated, viz. that withinſide a veſſel, the lateral partieles direct themſelves towards the orifice with a motion more or leſs oblique; and this oblique motion may be decompoſed into two forces, the one parallel to the plane of the orifice, and which contracts the ſtream; the other perpendicular to the ſame plane, and the only one which produces the efflux.

This contraction occurs alſo when water is made to flow through pipes, and that at the entrance of the water into the pipe, and not at its exit, where the ſtream preſerves a cylindrical form. I ſhall prove that this contraction diminiſhes, in a ſenſible manner, the quantity of water which would naturally flow.

In order to aſcertain theſe facts by experiment, many have been made. In all the following inſtances the orifices, through which the water flowed, were pierced perpendicularly through plates of copper of about one-twenty-fourth of an inch thick, and the time of each experiment is reduced to one minute.

The conſtant height of the water above the center of each orifice was 11 feet 8 inches 10 lines.

		No. of cubic inches, furniſh-ed in 1 minute.
Expt. 1.	Through an horizontal circular orifice of $\frac{1}{2}$ inch (6 lines) diameter - -	2,311
2.	Through ditto of 1 inch diameter - - -	9,281
3.	Through ditto of 2 inches diameter - - -	37,203
4.	Through an horizontal rectangular orifice of 1 inch long and $\frac{3}{12}$ inch wide -	2,933
5.	Through an horizontal ſquare orifice of 1 inch the ſide -	11,817
6.	Through ditto of 2 inches each ſide of the orifice -	47,361
Conſtant height = 9 feet.		
7.	Through a lateral circular orifice of $\frac{1}{2}$ inch diameter -	2,018
8.	Through ditto of 1 inch diameter - - -	8,135
Conſtant height = 4 feet.		
9.	Through a lateral circular orifice of $\frac{1}{2}$ inch diameter -	1,353
10.	Through ditto, of 1 inch diameter - - -	5,436
Conſtant height = $\frac{7}{12}$ inch.		
11.	Through a lateral circular orifice of 1 inch diameter -	628

It follows from the preceding table,

1. That the quantities of water diſcharged in the ſame time, by different apertures, under the ſame height of ſurface in the reſervoir, are to each other nearly as the areas of the apertures. Compare together the reſults of the ſecond and third experiments, of which the areas of the orifices are in the proportion of one to four, and it will be found that the quantities of water afforded, viz. nine thouſand two hundred and eighty-one cubic inches, and thirty-ſeven thouſand two hundred and three inches, are very nearly in the ſame proportion.

2. That the quantities of water diſcharged in the ſame time through the ſame aperture, under different heights of ſurface in the reſervoirs, are to each other nearly as the ſquare roots of the correſponding heights of the water in the reſervoir above the center of the aperture. Compare together the reſults of the eighth and tenth experiments, where the heighths of the reſervoirs are nine and four feet, the ſquare roots of which are three and two, and it will be found that the two quantities of water, eight thouſand one hundred and thirty-five cubic inches, and five thouſand four hundred and thirty-ſix cubic inches, which run through the ſame orifice of one inch diameter under the different heights of nine feet and four feet, are to each other nearly in the proportion of three to two.

3. That in general the quantities of water diſcharged in the ſame time through different apertures, under different heights of ſurface in the reſervoirs, are to each other as the areas of the aper-

tures are to the ſquare roots of the heights of water in the reſervoirs.

4. That in conſequence of the friction, the ſmall apertures furniſh a leſs quantity of water in proportion than the great ones, under the ſame height of water in the reſervoir; becauſe, comparatively to the extent of the area of each orifice, there are more points of friction againſt the ſides of the orifice in the ſmall than there are in the great ones; for the circumferences do not diminiſh ſo much as the areas.

5. That of many apertures of equal areas, that of which the circumference is the leaſt will, on account of the friction, furniſh more water than the others, under the ſame height of the reſervoir; circular apertures are, for this reaſon, the moſt advantageous of all; for the circumference of a circle is the ſhorteſt line that can be made uſe of to incloſe a given ſpace; therefore there is leſs ſurface of friction relatively to the ſize of the area.

It is eaſy to perceive, that the quantity of water diſcharged in the table of experiments is not near ſo great as might be expected from the extent of the areas and the heights of the reſervoirs. The quantity is in fact diminiſhed by the friction, and ſtill more by the contraction of the ſtream; for the velocity which is in proportion to the entire altitude of the fluid is not ſenſibly changed. Suppoſing, firſt, that the area of the ſtream is the ſame as that of the orifice; and ſuppoſing, ſecondly, that the ſtream is contracted, then the difference of the quantities afforded is as ſixteen to ten; that is, ſuppoſing the area of the aperture to be diminiſhed in the proportion of ſixteen to ten, the diſcharge of the fluid out of veſſels kept equally full may be determined with ſufficient exactneſs. By the expreſſion, *an inch of water*, is underſtood the quantity which flows out of a circular and lateral orifice of one inch diameter, the ſurface of the water being conſtantly kept ſeven-twelfths of an inch above the center of the orifice. This is the caſe with the eleventh experiment in the preceding table, where it appears that the quantity of water furniſhed is ſix hundred and twenty-eight cubic inches. M. Mariotte, who made the ſame experiment, found the quantity to be a little more; but it is probable that he might commit a ſmall error, becauſe the experiment I have juſt cited was made, M. Briſſon informs us, with the utmoſt care and attention. A (French) pint of water, he adds, inſtead of weighing two pounds, as is commonly believed, is proved to fall ſhort of that weight conſiderably, as will be evident by ſtrictly examining that experiment.

Theſe facts being premiſed, I ſhall requeſt the attention of the reader, ſecondly, to the diſcharge of fluids through additional pipes.

When, inſtead of cauſing water to paſs through an aperture made in a thin ſubſtance, it is made to flow through an additional vertical pipe of the ſame diameter with the orifice, the quantity of water diſcharged is more conſiderable, becauſe the contraction of the ſtream is greater in the firſt caſe than in the ſecond.

In the following experiments, the conſtant height of the water in the reſervoir above the upper baſe of the additional vertical pipe is 11 feet $8\frac{10}{12}$ inches (French) and the diameter of the pipe one inch.

	The variable heights of the tube expreſſed in lines.		Number of cubic inches of water diſcharged in one minute.
	Lines.		
Exper. 1.	- - 48	The water running through a full pipe.	- - 12,274
2.	- - 24		- - 12,188
3.	- - 18		- - 12,168
4.	- - 18	The water not filling the pipe.	- - 9,282

It appears from this table of experiments, that the longer the vertical pipe is, the greater will be the quantity of water diſcharged, becauſe the contraction of the ſtream is leſs, as may be ſeen by comparing the three firſt experiments. There is always, however, ſome contraction, though the water appears to flow out of a full pipe.

In comparing the quantities of water diſcharged in the third and fourth experiments, it will appear, that the two quantities, 12,168 cubic inches and 9,282 cubic inches, are to each other nearly in the relation of thirteen to ten; but it has been obſerved before, that the quantity of water diſcharged through an aperture made in a thin ſubſtance, if the ſtream was not contracted, would be to the quantity

tity of water diſcharged through the ſame orifice, if the ſtream was contracted, nearly as ſixteen to ten. Hence then it may be concluded, that the height of the water in the reſervoir and the different apertures being the ſame, the quantity of water diſcharged through an orifice made in a thin ſubſtance, in which there was no contraction of the ſtream, the quantity of water diſcharged through an additional pipe, and the quantity which would flow through an orifice made in a thin partition, in which there was a contraction of the ſtream, are to each other nearly as the three numbers, ſixteen, thirteen, ten, and theſe proportions are found ſufficiently accurate for common purpoſes.

Hence alſo it may be inferred, that additional pipes counteract only in part the contraction of the ſtream. The moſt ſenſible of all contractions of this nature is that which takes place when water flows from a large reſervoir through a ſmall aperture made in a thin ſubſtance.

If the additional pipe, inſtead of being vertical, or placed in the bottom of the veſſel or reſervoir, is horizontal, or placed in the ſide, it will afford the ſame quantity of water, provided that it is of the ſame length, and that the exterior aperture is placed at the ſame diſtance below the ſurface of the water in the reſervoir.

If the additional pipe, inſtead of being cylindrical, is conical, having its largeſt baſe attached to the ſide of the reſervoir, it will produce a much greater quantity of water. The moſt advantageous form, indeed, for procuring the greateſt quantity of water in a given time through a certain aperture, is that which the ſtream itſelf naturally aſſumes in coming out of an aperture in a thin ſubſtance; that is, the form given to the pipe ſhould be that of a truncated cone, the diameter of the ſmaller baſe of which ſhould be the ſame as that of the aperture through which the water is to flow.

It is neceſſary alſo, that the area of the ſmaller baſe ſhould be to the area of the greater as ten to ſixteen; and the diſtance between the two baſes ſhould be nearly equal to half the diameter of the greater baſe. The remainder of the length of the pipe may be either cylindrical or priſmatic. The diſcharge will then be equally abundant with that which would take place through an aperture equal to the ſmaller baſe made in a thin partition, and in which the ſtream ſuffered no contraction. This form may be applied to practice whenever it is required to draw a certain quantity of water from a river by an aqueduct, &c. through a canal or lateral pipe.

If we compare the different quantities of water diſcharged through additional pipes of different diameters with different altitudes of the water in the reſervoirs, we ſhall have the reſults ſtated in the following table, the additional pipes being ſuppoſed to be two inches long, and vertical, or placed in the bottom of the reſervoir.

The conſtant height of the water above the aperture.		The diameter of the additional pipes in twelfths of an inch (lines).		No. of cubic inches diſcharged in one minute.
Ex. 1.	552 lines.	6	The water running through a full pipe.	1,689.
2.		10		4,703.
3.		6	The water not following the ſides.	1,293.
4.		10		3,598.
5.	288 lines.	6	The water running through a full pipe.	1,222.
6.		10		3,402.
7.		6	The water not filling the tube.	935.
8.		10		2,603.

The firſt inference from theſe experiments is, that the quantity of water diſcharged by different additional pipes, under the ſame height of water in the reſervoir, is proportional to the areas of the apertures, or to the ſquares of their diameters.

Secondly, it appears that the quantities of water diſcharged through additional pipes of the ſame diameter, under different altitudes of water in the reſervoir, are proportional to the ſquare root of the altitude.

Thirdly, that in general the quantities of water diſcharged in the ſame ſpace of time through different additional pipes, under different heights of water in the reſervoir, are to each other nearly as the product of the ſquare of the diameters of the pipes by the ſquare root of the altitude of the reſervoirs.

The efflux of water, therefore, through additional pipes, follows the ſame laws as water when diſcharged through apertures made in thin ſubſtances. On theſe experiments the following table was formed, of the quantities of water diſcharged through a given aperture made in a thin ſubſtance, ſuppoſing the ſtream to ſuffer no contraction, or through the ſame aperture with a contraction of the ſtream, or through the ſame aperture with an additional pipe.

Conſtant height of the water in the reſervoir above the aperture, expreſſed in (French) feet.	Cubic inches of water diſcharged in one minute through an aperture of one inch diameter without any contraction of the ſtream.	Cubic inches of water diſcharged in one minute through an additional pipe of one inch diameter and two inches long.	Cubic inches of water diſcharged in one minute through an aperture of one inch diameter with a contracted ſtream.
1	4381	3539	2722
2	6169	5002	3846
3	7589	6126	4710
4	8763	7070	5436
5	9797	7900	6075
6	10732	8654	6654
7	11592	9340	7183
8	12392	9975	7672
9	13144	10579	8135
10	13855	11151	8574
11	14530	11693	8990
12	15180	12205	9384
13	15797	12699	9764
14	16393	13197	10130
15	16968	13620	10472

III. There is no application of the doctrines of hydraulics more ſurpriſing, or more gratifying to the eye, than that which is ſeen in the variety of artificial fountains, or jets d'eau, which the ingenuity of man has been able to conſtruct for ornament in general, and for uſe in ſome inſtances, particularly in warm climates. The principles on which theſe are conſtructed it will not be difficult, after what has been ſtated, fully to comprehend.

Whatever may be the direction of the jet or fountain, the quantity of water expended will be the ſame, provided that the adjutage*, and the height of the reſervoir above the adjutage, is the ſame. This is a neceſſary conſequence of the equal preſſure of fluids in all directions.

Water, when diſcharged through an ajutage, however ſmall it may be, has a velocity ſufficient to raiſe it to the height of the ſurface of the water contained in the reſervoir; ſo that a vertical jet d'eau throws up the water as high as the reſervoir whence it proceeds, if nothing obſtructs it.

There are, however, many cauſes which contribute to diminiſh the elevation of water by jets d'eau. Firſt, the friction in the pipes from the reſervoir to the ajutage; ſecondly, the friction againſt the circumference of the aperture; thirdly, the reſiſtance of the air to the motion of the column; fourthly, the gravity of the particles of water themſelves, which, in riſing, loſe ſome of their velocity, and recoil upon thoſe which ſucceed them.

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* A tube which is fitted to the mouth of the veſſel through which the fountain is played.

Thus, by inclining the pipe a little, we find that the water will riſe higher than when it is exactly vertical; but in this caſe, the effect is not ſo agreeable to the eye of the ſpectator, as when the water which riſes above the pipe into the air falls perpendicularly, in a manner, back upon itſelf.

When the ajutage is placed in an oblique direction to the horizon, the force of the projection and the gravity of the water cauſe the ſtream which aſcends into the air to form a parabola, the amplitude of which is in proportion to the height of the reſervoir.

When the ajutage is placed horizontally, the water forms a ſemi parabola.

Fountains elevate the water in proportion as the aperture of their ajutages is large; becauſe, firſt, if two jets d'eaux proceeding from the ſame reſervoir, and flowing from their ajutages with an equal degree of velocity, the greater will, in the firſt place, experience leſs friction; and ſecondly, it has a greater maſs, and conſequently more power to overcome the obſtacles which may oppoſe it.

But, though large jets d'eau elevate water higher than ſmall ones, they do not expend a greater quantity in proportion; for the quantity of water diſcharged is as the product of the aperture of the ajutage by the degree of velocity at the time of the diſcharge; and this velocity is the ſame in both, no allowance being made for the friction.

In order to make large fountains elevate water higher than ſmall ones, it is evidently neceſſary that the conducting pipes ſhould be ſufficiently large to furniſh water in abundance; for if they are ſmall, experience proves that the ſmall fountains in that caſe will elevate water higher than larger ones; it follows then, that the diameter of the pipe, which conveys the water, ſhould be in proportion to that of the ajutage, in order to elevate the water to the greateſt poſſible height.

If we compare two different jets d' eau, and are deſirous that each ſhould elevate water to the greateſt poſſible height, it is neceſſary that the ſquares of the diameters of the conduit pipes ſhould be in proportion to each other in the compound ratio of the diameters of the ajutages and the ſquare root of the altitudes of the reſervoirs. Thus, if it is known by experiment what the diameter of a conduit pipe ſhould be, to ſupply an ajutage of given dimenſions, it may be eaſily determined what the diameter of another pipe ſhould be to furniſh another ajutage of a determinate ſize, the height of the reſervoir being alſo given.

It has been proved by experiments, that when the diameter of the ajutage is half an inch, and the height of the reſervoir fifty-two feet, the diameter of the pipe which conducts the water ought to be three inches and a quarter; and that for an ajutage of half an inch diameter, the height of the reſervoir being ſixteen feet, the diameter of the pipe ought to be about two inches and one-third. There is no inconvenience in making the conduit pipe of a greater diameter than is required by this rule; but on the contrary, there would be an inconvenience in making it of a ſmaller diameter.

Sometimes the ajutage is made in the form of a cone, and ſometimes in that of a cylinder; but thoſe who conceive that it is indifferent in which of thoſe forms it is made are miſtaken, for the cylindrical form is by far the moſt diſadvantageous.

By comparing many experiments made upon artificial fountains, it has been determined, that the differences between the altitudes of vertical jets and the height of their reſervoirs are to each other as the ſquares of the altitudes of the former. If then it is known what quantity of water a jet elevates at a certain height of the reſervoir, the quantity which any other jet of a given height will elevate, compared with the height of its reſervoir, may be eaſily found by the rule of ſingle proportion.

When it is neceſſary to bend the conducting pipes, the utmoſt care ſhould be taken to avoid bending them at right angles, for the ſtriking of the current againſt theſe angles very conſiderably diminiſhes the velocity.

The following table will greatly facilitate the application of theſe principles.

The heights of jets, and the correſpondent heights of reſervoirs, are found in the two firſt columns. The third column contains in (Paris) pints, of which thirty ſix make a cubic foot, the quantities of water diſcharged in one minute through an ajutage of half an inch diameter, relatively to the heights in the ſecond column. The quantity diſcharged through an ajutage of half an inch diameter being known, the quantity which will be diſcharged by any other ajutage, under the ſame height of the reſervoir, may be found by ſingle proportion; for it has already been proved, that the quantities of water diſcharged are to each other as the areas of the ajutages, or as the ſquares of their diameters. In the fourth column are found the diameters for the conducting pipes of an ajutage of half an inch diameter, according to the heights in the ſecond column. The diameters of pipes for other ajutages, and other heights of the reſervoir, are found by following the preceding rule.

Fractions are not obſerved in the calculations for the two laſt columns.

The heights of jets, expreſſed in feet.	The heights of reſervoirs, in feet and inches.		Quantities of water diſcharged in one minute through an ajutage of half an inch diameter, in pints.	Diameters of the pipes, according to the 2d and 3d columns, in lines.
Feet.	*Feet.*	*Inches.*	*Pints.*	*Lines.*
5	5	1	32	21
10	10	4	45	26
15	15	9	56	28
20	21	4	65	31
25	27	1	73	33
30	33	0	81	34
35	39	1	88	36
40	45	4	95	37
45	51	9	101	38
50	58	4	108	39
55	65	1	114	40
60	72	0	120	41
65	79	1	125	42
70	86	4	131	43
75	93	9	136	44
80	101	4	142	45
85	109	1	147	46
90	117	0	152	47
95	125	1	158	48
100	133	4	163	49

IV. From objects of mere pleaſure and ornament, our attention is next ſolicited to an invention of eminent utility, and of ancient date, though the modern improvements are very conſiderable even in this branch of mechanics.

Pumps are hydraulic engines, deſigned for the purpoſe of elevating water; they are compoſed of hollow cylinders AB (Plate VII. Fig. 3.) or EF (Plate VIII. fig. 1.) of an equal diameter throughout their whole length, which is called *the body of the pump*, and in which a kind of ſtopple I, called the *piſton*, is made to ſlide, or move up and down. The piſton is put in motion by means of a rod of metal X *x*, at the extremity of which X the handle is placed, and elevated by the lever X Y, or by ſome other contrivance; to this is annexed a pipe A T (Plate VII. Fig. 3.) to conduct the water to the height required; and, laſtly, the ſuckers S *s*.

There are ſeveral kinds of pumps; ſome are called ſucking pumps and others forcing pumps, and there are others which are at the ſame time both ſucking and forcing pumps.

The *raiſing pump* is compoſed of the body of the pump A B, (Plate VII. Fig. 3.) to the lower part of which is affixed the end of a pipe B N, open at the bottom, or (which is ſtill better) pierced with holes its whole length, in ſuch a manner that large pieces of dirt and rubbiſh may be prevented from entering the body of the pump. At the union of this end of the pipe with the body of the pump is placed a valve or ſucker *s*, which, when raiſed up by the preſſure of the water beneath, permits the fluid to aſcend into the body of the pump, but which, by being preſſed down again by the action of the pump, prevents effectually the efflux of the water by the ſame aperture. In the body of the pump there is a box or piſton I, pierced quite through, furniſhed at the upper end with a ſucker S, and joined at *x*, by the aſſiſtance of a head ſomewhat in the form of that of a pair of compaſſes, to the rod *x* X, which enables it to act by the aid of a lever X Z Y. At the upper part A of the body of the pump is placed the raiſing pipe A T, which has its ſpout in T. This pump ought to be placed in a well or baſon, in ſuch a manner that the body of the pump A B ſhould be entirely under the ſurface of the water A A.

Now if the piſton I is raiſed by lowering the extremity Y of the lever Y Z X, ſo that the lever may aſſume the poſition *y* Z *u*, the piſton will riſe in the body of the pump, where it will create an imperfect vacuum equal to the diſtance X *u*, and conſequently the water beneath will raiſe the ſucker *s*, and will paſs out of the baſon into the pump. When the piſton is lowered again, this preſſure cauſes the ſucker *s* to cloſe, and the ſucker S to riſe up; hence the water which was below the piſton is then above it. By a ſecond exertion of the piſton, this quantity of water is elevated, and by the ſame mechaniſm a freſh quantity is permitted to paſs into the pump, and afterwards to riſe above the piſton, in the ſame manner as the firſt portion was raiſed; ſo that by a certain number of exertions of the piſton, the raiſing pipe A T is filled. When this

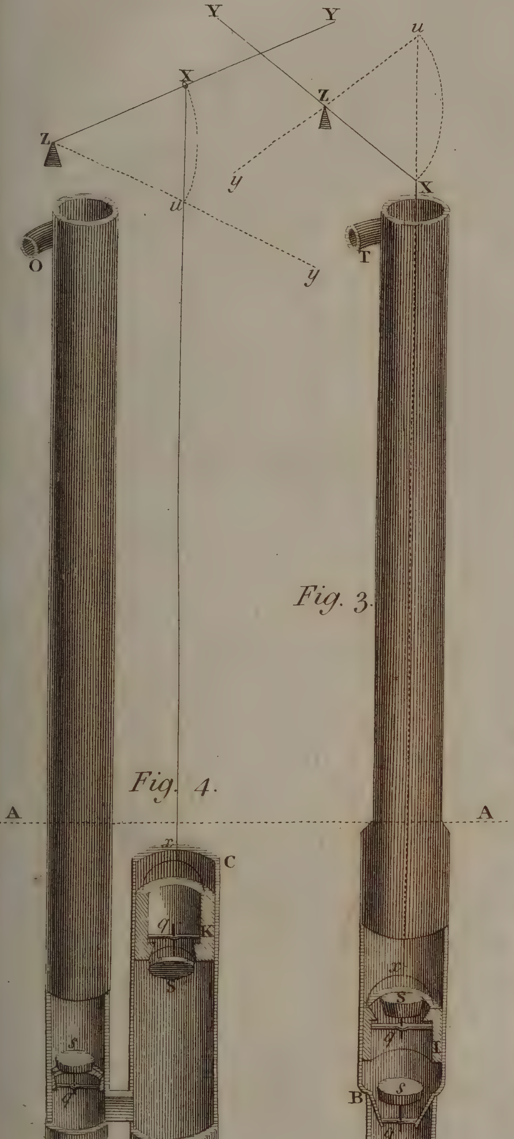
Fig. 3.

Fig. 4.

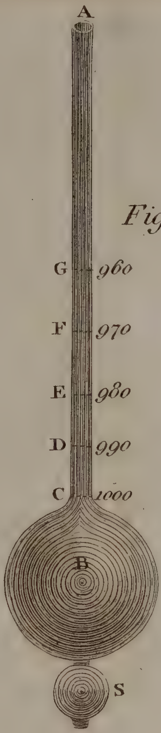
Fig. 1.

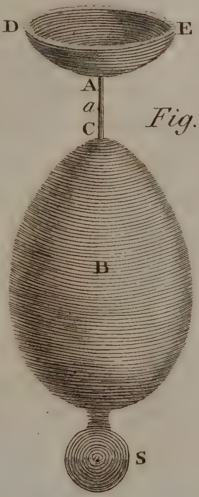
Fig. 2.

this is accompliſhed, at every exertion or ſtroke of the piſton there is ejected at the ſpout or diſcharging pipe T a maſs of water equal to a cylinder, the baſe of which is equal to the width of the piſton, and of a height equal to the ſpace through which the piſton paſſes in the body of the pump. This ſpace is commonly called the play of the piſton.

It is not difficult to eſtimate the weight of the column of water with which the piſton is charged, when the raiſing pipe is full, and conſequently the force which is neceſſary to be exerted in Y in order to work the pump. It has been obſerved before, that fluids preſs in proportion to their perpendicular height, and the width of the baſe which oppoſes their deſcent. In a pump, this baſe is the piſton, and the perpendicular height is that of the raiſing pipe above the ſurface of the water; ſo that when the raiſing pipe is full, the charge upon the piſton is equal to the weight of a cylinder of water, the diameter of which is equal to that of the piſton, and the height equal to that of the raiſing pipe above the ſurface of the water, whatever may be the diameter of the mounting pipe; and this charge or weight upon the piſton is eaſily calculated, when it is known that a cylinder of water of one foot diameter and one foot high weighs about fifty-five (French) pounds.

It follows, therefore, that the weight of a column of water is not diminiſhed by diminiſhing the diameter of the raiſing pipe; but that, on the contrary, the reſiſtance which ought to be overcome is even augmented on account of the increaſe of the friction, which is more conſiderable in ſmall pipes

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than in large ones, becauſe the relative ſurfaces augment as the diameters diminiſh. Thus, only for the expence, it would be wrong to make, as is commonly done, the raiſing pipe ſmaller than the body of the pump; on the contrary, it would be better to conſtruct it of a diameter greater than that of the body of the pump, as the friction would be proportionably diminiſhed.

The *forcing pump* is compoſed of the body of the pump C D, (Plate VII Fig 4.) ſtopped cloſe at the bottom, but entirely open above, and in which is a piſton K, which only differs from that of the pump already deſcribed in this, that its ſucker S is placed at the bottom inſtead of the top. This piſton, like that of the pump juſt mentioned, is put in action by means of the lever Y X Z, which has its point of ſupport in Z. The raiſing pipe A O is placed at the ſide of the body of the pump, with which it communicates, and is furniſhed with a ſucker *s* in its lower part, and with a ſpout O at its upper extremity. This pump, as well as the preceding, ought to be immerſed in a well or baſon in ſuch a manner that the body of the pump C D ſhould be entirely under the ſurface of the water A A.

The water fills the body of the pump by falling through the aperture C, and by paſſing over the piſton K, the ſucker of it S, conſidering its poſition, will naturally open. If the piſton K is lowered, by placing the lever Y X Z in the poſition *y u* Z, the réſiſtance of the water againſt the ſucker S will cloſe it immediately. This water then, being incapable of repaſſing above the piſton, is forced up the pipe A O, by raiſing up the ſucker *s*. As ſoon as the piſton is raiſed again, the ſucker *s* is cloſed by the preſſure of the water which is above, and the ſucker S is opened by its own weight. A new maſs of water then paſſes below the piſton, which, by a ſecond depreſſion of the piſton, is forced to paſs, like the firſt, into the pipe A O; ſo that by a certain number of ſtrokes of the piſton that pipe becomes full of water, which is then diſcharged at the ſpout O as in the pump already deſcribed. If the piſtons in both of them are of the ſame diameter, and the raiſing pipes of the ſame perpendicular height, the weight of the two columns of water will be equal, and the two pumps will require the ſame power to work them; for in that caſe it requires the ſame power to elevate the piſton charged with a column of water as it does to force the column of water with the piſton.

The ſucking* pump (Plate VIII. Fig. 1.) is compoſed of the body of the pump E F, open above, and with a pipe of aſpiration or ſucking pipe F P adapted to the lower part. At the union of this pipe with the body of the pump is a ſucker *s*, deſigned to permit the water, while the piſton is raiſed, to enter through the pipe of aſpiration P F into the body of the pump F E, and to prevent it, while the piſton is lowering, from being diſcharged the ſame way. In the body of the pump is a

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[*] So called, becauſe it was originally ſuppoſed, but erroneouſly, to act by ſuction.

piſton L, made like that at I in Plate VII. Fig. 3. and which is put in action in the ſame manner by the aſſiſtance of the lever X Z Y. This pump ſhould be placed in ſuch manner as to have only the lower extremity of the aſpiration pipe F P plunged into the water.

While the pump remains inactive, the two ſuckers S and *s* are naturally cloſed from their own weight. If the piſton L is raiſed up by means of putting the lever X Z Y in the ſituation *u* Z *y*, the column of air which reſts above is elevated, and the air which is cloſed up in the aſpiration pipe, from the ſurface of the water *a* to the piſton, having then more ſpace to occupy, becomes more rarified than the external air. This laſt then preſſes more forcibly upon the ſurface of the water *a*, and cauſes it to riſe in the aſpiration pipe, till the interior air has regained its former denſity by occupying leſs ſpace. Thus, after ſeveral ſtrokes of the piſton, the water reaches the body of the pump, and paſſes over the piſton, by raiſing up the ſuckers *s* and S, one after another, and the piſton, by its ſubſequent elevation, forces the water to eſcape at the ſpout E.

As it is the preſſure of the air which cauſes the water to riſe in this pump, and as this preſſure can ſuſtain only a column of water of about thirty-two feet, it is clear that the aſpiration or ſucking pipe ſhould not exceed that length. In common practice it is indeed ſeldom made ſo long as thirty-two feet. In order that the preſſure of the atmoſphere may be ſuch as to ſuſtain a column of water of that height, it is neceſſary, firſt, that the ſucking pump ſhould be made with the greateſt exactneſs, and that it ſhould continue in a perfect ſtate; ſecondly, that it ſhould be placed upon the level of the ſea, or very near it, becauſe it is there that the preſſure of the atmoſphere is moſt forcible; thirdly, that the preſſure of the air ſhould not vary; but in general all theſe circumſtances are not required. Mechanics are ſatisfied, in general, with making the aſpiration pipe twenty-three or twenty-four feet long. If it is neceſſary to elevate water to a greater height, the forcing pump is more commodious for that purpoſe. The latter, it is true, is ſubject to ſeveral inconveniencies. It is neceſſary to place the body of the pump either in wells or in a baſon; and when it is required to repair it, which often happens, one of two things is neceſſary, either to empty the well or the baſon, or to draw up the body of the pump, which is extremely troubleſome and expenſive. To remedy theſe inconveniencies, the beſt and moſt uſual mode is, when water is to be elevated from a great depth, to make the pump at once both a forcing and ſucking pump, in the manner which I ſhall preſently explain.

In the year 1766 it was reported, through the channel of the public papers, that at Seville, in Spain, a ſimple ſucking pump had been conſtructed, which elevated water to the height of ſixty feet, and it was conſequently concluded, that the world had till then been notoriouſly impoſed upon by the current maxim, that the preſſure of the air could raiſe a column of water only to the height of thirty-two feet,

feet. M. Briſſon has carefully examined into the fact, and his explanation is curious and intereſting.

An ignorant tinman, at Seville, had made a ſucking pump ſixty feet long, becauſe he had occaſion to elevate the water to that height. When the pump was fixed in its place, and put in action, he was unable to make the water riſe into the body of the pump. Enraged at this diſappointment, he gave it a blow with his hammer, which produced a a ſmall aperture in the aſpiration pipe at about ten feet above the ſurface of the water in the baſon. Immediately a ſmall portion of water arrived at the body of the pump. After this proceſs it was reported, that a ſucking pump had been conſtructed, which elevated water to the height of ſixty feet; but the reader will be enabled to judge of the truth of this aſſertion from the following obſervations:

Let us ſuppoſe that the aſpiration pipe, P F (Plate VIII. Fig. 1.) had from *a*, the ſurface of the water of the baſon, to F, a diſtance of ſixty feet, and that after a certain number of ſtrokes of the piſton, the water riſes to *c*, thirty two feet high; if then a ſmall hole is made at *b*, ten feet above the ſurface of the water, the air which enters at this hole, and preſſes in all directions, will cauſe the column of water of ten feet, which is below *b*, to fall into the baſon, and the preſſure of the air upwards at *b* has only a column of water of twenty-two feet to ſupport.

But that preſſure is capable not only of raiſing that column to the height of ſixty feet, but even to the height of eight thouſand feet; for air, near the ſurface of the earth, is eight hundred times leſs denſe than water, and ſuppoſing (which is not the caſe) it was not diminiſhed in elevating, then the ten feet of water, cut off by the preſſure of the air at *b*, downwards, would be more than equivalent to eight thouſand feet of air. The column of air, therefore, which preſſes at *b*, will be too ſtrong for more than eight thouſand feet; thus the twenty two feet of water remaining above will not be in equilibrium with the column of air till after it has riſen higher than eight thouſand feet.

In order to have a ſecond portion of water with a pump of this conſtruction, it is in the firſt place neceſſary to ſtop the aperture which was made at *b*, then to give ſeveral ſtrokes with the piſton to elevate the water as high as *c*; and laſtly, to open again the orifice at *b*. Obſerve the ſimplicity of this proceſs for raiſing ſo ſmall a quantity of water! for it is neceſſary that the aſpiration pipe ſhould be of a very ſmall diameter, otherwiſe the column of water would break, and the air would paſs through, and not one drop of water could be raiſed into the body of the pump. This fact (adds M. Briſſon) may ſerve to convince thoſe who are fond of novelty, that before an opinion generally received is pronounced to be falſe, it is neceſſary to think twice at the leaſt. A ſhort time after the conſtructing of this pump at Seville, M. Bellangé, a goldſmith in Paris, made one in imitation of it, to which he gave the additional property of throwing water fifty-five feet high, by means of a continued *jet* or ejecting pipe, though the machine was only a ſimple ſucking pump.

To a ſmall bodied pump of two inches and one-twelfth in the interior diameter, the piſton of which had eight inches play, he adapted an aſpiration pipe of ten twelfths of an inch diameter, and fifty-ſix feet long; this pipe was furniſhed with a ſucker at its junction with the body of the pump, and with another at its lower extremity. This extremity was plunged into a tun full of water. M. Bellangé had made a ſmall perforation in this pipe of about one twenty-fourth of an inch diameter, at twelve or fifteen inches above the ſurface of the water in the tun. The apparatus being diſpoſed of in this manner, he moved the piſton gently, but the water did not riſe; the ſmall hole furniſhed a ſufficient quantity of air to fill the aſpiration pipe. He then moved the piſton with great velocity; the ſmall hole could not, in ſo ſhort a ſpace of time, furniſh a ſufficient quantity of air to fill the pipe; a little water roſe and mixed itſelf with the air, ſo that the column became compoſed of ſmall cylinders, alternately of air and water, and though it was fifty-five feet high, it was much ſhort of the weight of a column of water thirty-two feet high. If we calculate, therefore, according to the diameter of the body of the pump, and the extent in which the piſton played, what quantity of water this pump would have furniſhed if the air had not entered, and then compare this quantity with that which it really furniſhed, we ſhall find that the latter is greatly inferior;

for in ſix minutes five hundred and thirty ſtrokes of the piſton may be given, which would furniſh only thirty ſix pints of water; this pump, therefore, would not furniſh the eighth part of the water which it ought to do upon the common principles of the ſucking pump; ſo that though the conſtruction might appear to be more ingenious, it was not in reality to be preferred to that of Seville.

The *compound forcing pump* is compoſed of the body of the pump G H, (Plate VIII. Fig. 2.) open above, and the aſpiration pipe H V adapted to the lower end. At the union of this pipe with the body of the pump is a ſucker S, deſigned for the ſame uſe as in the ſimple ſucking pump. In the body of the pump is a piſton M, not pierced as the preceding, but ſolid, and put in action by the aid of the rod *x* X, and of the lever Y X Z, which has its point of ſupport, or fulcrum, in Z. At the ſide of the pump, and towards the bottom of its body, is adapted a raiſing pipe H R, furniſhed with a ſucker *s* near its baſe, and with a ſpout R near its ſuperior extremity. This pump ought to be placed in ſuch a manner that the lower extremity only of the aſpiration pipe H V ſhould be immerſed under water.

It is eaſy to perceive that the firſt action of this pump will be the ſame as that of the ſucking pump, which has been deſcribed; for if the piſton M is raiſed by putting the lever Y X Z in the ſituation *y u* Z, the column of air which reſts above will be elevated; the air which is in the aſpiration-pipe will become, by that means, rarer than the exterior air. The latter then preſſes more forcibly upon the ſurface of the water A A, and carries it, after ſome ſtrokes of the piſton, into the body of the pump; when it is arrived there, if the piſton M is lowered, the ſucker S will cloſe, and the water is forced along the raiſing-pipe H R, by the riſing of the ſucker *s*, which, as ſoon as the preſſure ceaſes, falls again from its own weight and that of the water above it.

This pump is very convenient, on account of its body being placed out of water, which affords an opportunity of making the neceſſary repairs with facility, and alſo on account of its being capable of carrying water to any height which may be required: in order to effect this, all that is neceſſary is, to lengthen the raiſing-pipe, and to augment the power which puts the pump in action. I believe this is at preſent the moſt uſual form of what are called forcing pumps in this country.

The fire engine is an hydraulic engine, which may be claſſed with the pump that I have now deſcribed. It is at once a ſucking and forcing pump, but has a continued *jet*, or ejecting pipe, though it has only one body. The eſſential parts of this pump are compoſed, like the compound pump, (Plate VIII. Fig. 2.) with this difference, that its aſpiration pipe is much ſhorter, and that inſtead of a ſolid raiſing pipe it has a leathern tube of a convenient length. This pump (Plate IX. Fig. 1.) is then compoſed of the body of the pump A H, open above, and to the lower part is adapted the aſpiration pipe

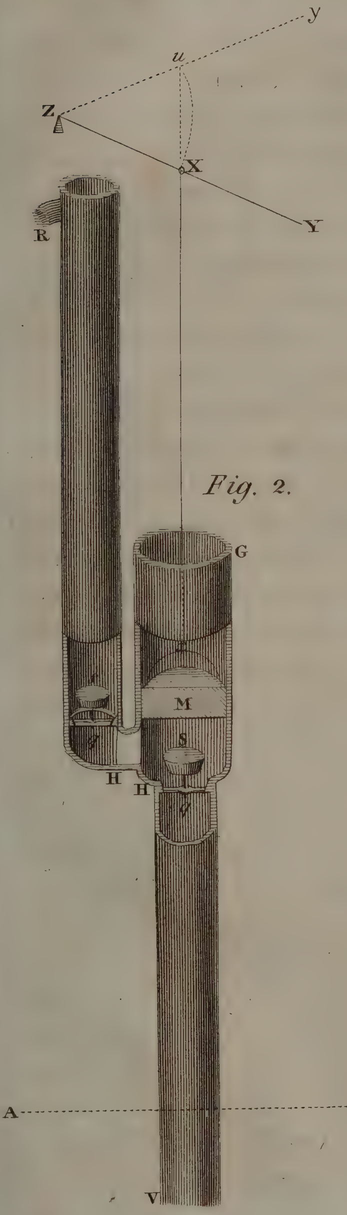


Fig. 2.

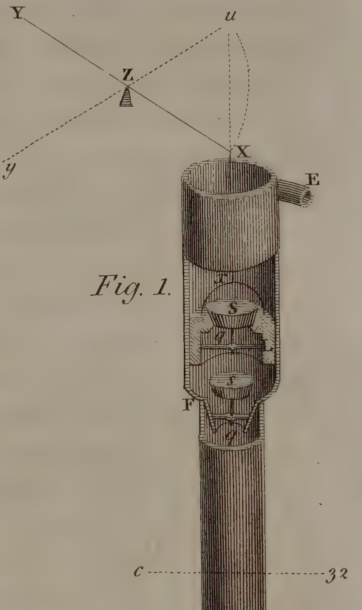


Fig. 1.

H T. At the union of this pipe with the body of the pump is placed a ſucker S, deſigned to prevent the water, which has once paſſed into the body of the pump, from returning into the baſon. In the body of the pump is a piſton M, not pierced but ſolid, and which is put in motion by the aid of a metal rod *x* X, and of a lever Y X Z, which has its fulcrum or point of ſupport in Z. Towards the bottom of the pump, in the ſide, is an aperture C, which is covered again by means of a valve *c l*, of which the tail *l* is the ſpring, and which is fixed on with a ſmall ſcrew. This valve is deſigned to prevent the water, which is expelled from the body of the pump, from entering again when the piſton M is raiſed. The body of the pump is ſurrounded with a pipe A B D E, about two or three inches more in diameter than the body of the pump; and the intermediate ſpace between them is filled with air. To the lower part of this pipe, and upon the ſide, is adapted another ſmall crooked pipe E R, furniſhed at the end R with a ſucker *s*, and with a ſcrew ferule, intended to receive a nut, by means of which the leathern pipe is joined to this end of the engine, and which ſerves inſtead of the raiſing pipe in the common forcing pump. All this apparatus is placed (as may be ſeen in Plate IX. Fig. 2.) upon a box or caſe N O lined with lead, which contains the water. The croſs bar Q ſupports the upper end F (Fig. 1.) of the body of the pump, which, for that purpoſe, is of a ſmaller diameter than the reſt; and the lid L (Fig. 2.) of the box has an aperture in the middle, to admit the aſpiration pipe H T to paſs through it.

From this explanation it will be evident, that if the piſton M is raiſed up by putting the lever Y X Z in the ſituation *y u* Z, the ſucker *s* and the valve *c*, placed in C, will be cloſed by the preſſure of the exterior air. This ſame preſſure, exerciſing its force upon the ſurface of the water V V, obliges it to paſs into the body of the pump by raiſing up the ſucker S. It then acts as a ſucking pump; but when the piſton M is lowered, its preſſure cloſes the ſucker S, and opens the valve which is in C; the water then paſſes, not only into the leathern pipe *a b d*, (Fig. 2.) by raiſing up the ſucker *s* (Fig. 1.) but alſo into the ſpace between the body of the pump and the pipe which incloſes it, by riſing towards I K, and compreſſes the air which is confined there. Immediately after the piſton M is raiſed again, that air, being no longer compreſſed, unfolds itſelf by its elaſticity, acts upon the water which is between the body of the pump and the pipe which incloſed it, and forces it alſo into the leathern pipe, ſo that when the piſton is lowered, the water is forced by the piſton itſelf, and when it is raiſed, the water is forced by the elaſticity of the air, which furniſhes a continued ſtream, though the pump has only one body or principal tube.

It is evident that theſe fire engines ſhould be able to furniſh a continued ſtream, and this can only be effected by employing the elaſticity of the air, while the piſton is riſing; but in order to effect this, a double force is required to put the pump in motion; in other words, a force capable of expelling the column of water, and an equal force to compreſs the air. But this is not an inconvenience, for, in caſe of fire, it very ſeldom happens that hands are wanting to aſſiſt; on the contrary, it frequently happens that the aſſemblage of people is rather too numerous.

Such is the engine which M. Briſſon has deſcribed, and it is, I preſume, that which is in common uſe in France. Its ſimplicity is admirable; yet I apprehend that our Engliſh fire engines are more powerful, and furniſh a more uninterrupted ſtream or current of water through the leathern pipe. In Fig. 3. is a repreſentation of our improved fire engine. This, the reader will ſee, is wrought by two forcing pumps, which act alternately; and the ſtream is made continual from the ſpring of air confined in a ſtrong metal veſſel C C, in the fire engine A B, fixed between the two forcing pumps D and E, wrought with a common double lever F G moving on the center H. The piſtons in D and E both ſuck and force alternately, and are here repreſented in their different actions, as are alſo the reſpective valves at I K and L M.

The water to ſupply this engine, if there is no opportunity of putting the end of a ſucking pipe, occaſionally to be ſcrewed on, into a moat or canal (which would ſpare much hurry and labour in caſe of fire) is poured into the veſſel A B; and being ſtrained through the wire grate N is, by the preſſure of the atmoſphere, raiſed through the valves K and M into the barrels of D or E, when either of their forcers aſcend; whence again, upon their deſcent, it will be powerfully propelled into the air-veſſel C C, through the valves I and L by turns: the common air then between the water and the top of the air-veſſel C C will from time to time be forcibly crowded into leſs room, and much compreſſed; and the air being in that condenſed ſtate poſſeſſed of a ſtrong and lively ſpring, and always endeavouring to dilate itſelf every way equally in ſuch a circumſtance, bears ſtrongly both againſt the ſides of the veſſel wherein it is confined, and the ſurface of the water thus injected; and thus produces a conſtant regular ſtream, which riſes through the metal pipe P into the leather one Q, and this latter being perfectly flexible, may be led about into rooms and entries, as the caſe may require.

Should the air contained in this veſſel be compreſſed into half the ſpace it took up in its natural ſtate, the ſpring of it will be nearly doubled; and as before it equalled and was able to ſuſtain the preſſure of the atmoſphere, ſince it has now a double force, by the power of that ſpring alone it will throw water into air of the common degree of denſity about thirty feet high. And ſhould this compreſſure be ſtill augmented, and the quantity of air, which at firſt filled the whole veſſel, be reduced into one-third of that ſpace, its ſpring will be then able to reſiſt, and conſequently to raiſe the weight of a treble atmoſphere; in which caſe it will throw up a jet of water ſixty feet high. And ſhould ſo much water again be forced into the veſſel as to fill three parts of the capacity, it will be able to throw it up about ninety feet high: and

Fig. 1.

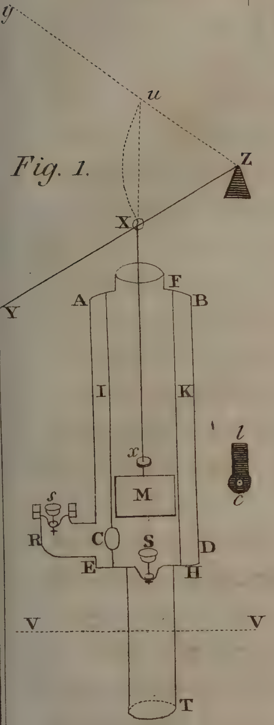


Fig. 2.

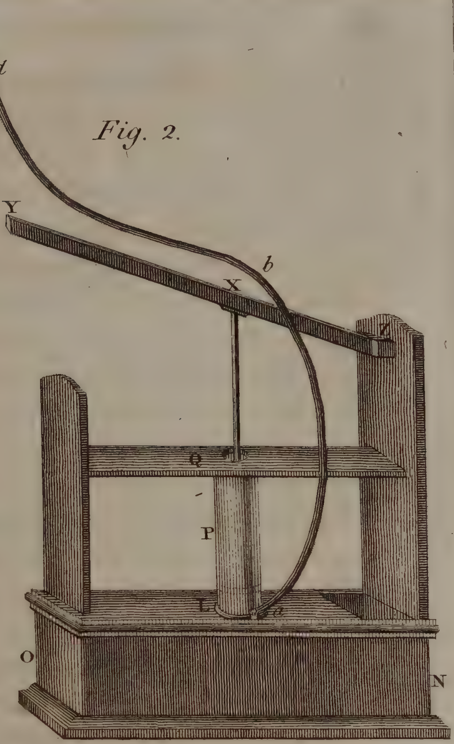
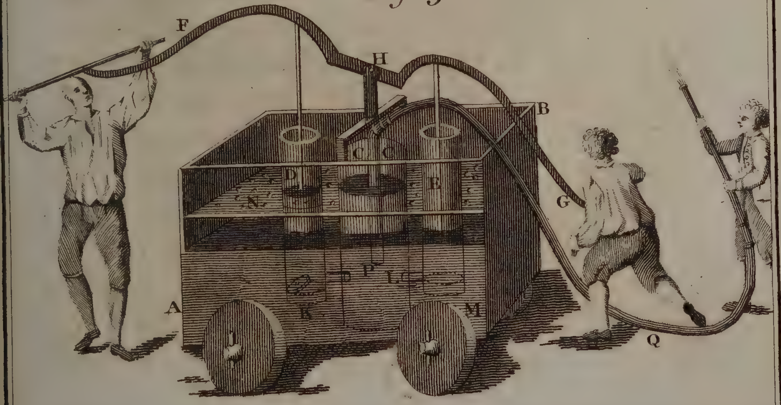


Fig. 3.



wherever the ſervice ſhall require a ſtill greater riſe of water, more water muſt be forced into this veſſel; the air therein being thus driven by force into a ſtill narrower compaſs, at each exploſion, its gradual reſtitution to its firſt dimenſions is what regularly carries on the ſtream between the ſtrokes, and renders it continual during the operation of the machine.

Various agents are employed to put pumps in action, ſuch as men, horſes, ſtreams of water, vapour, wind, &c. Small pumps, ſuch as thoſe in common wells, or fire engines, are generally wrought by men. When a conſiderable quantity of water is required to be raiſed, the moving power muſt be increaſed; and in order that a regular effort may be employed, or very nearly ſo, ſeveral additions are occaſionally made to the mechaniſm of pumps, ſo that when one ſet of piſtons deſcend another ſet may be made to riſe by the ſame force. The great engine at Marli is wrought by an apparatus of this kind.

The action of theſe engines depends upon the regularity of the alternate motion of the ſuckers or valves. It follows then, that theſe ſhould be ſo conſtructed and diſpoſed as perfectly to retain the water when they are cloſed, and to open eaſily when the action of the machine is directed to that object.

V. Of the motion of water in conduit pipes.

When it is required to conduct water from one place to another, it is very clear that the conducting pipes muſt be longer than the ſpace through which it is to be conveyed.

In treating of the diſcharge of water through additional pipes, I have taken but a curſory notice of the reſiſtance by friction, becauſe there it is ſcarcely perceptible; but it is not the ſame with reſpect to pipes of conſiderable extent; the friction of the water againſt their ſides leſſens conſiderably the velocity of the flowing water, as has been proved by experiments. I ſhall firſt ſpeak of rectilinear pipes.

In the following experiments two pipes were employed, one of an inch and a quarter diameter, and the other of two inches. The two pipes were ſucceſſively lengthened from thirty feet to one hundred and eighty; and the conſtant height of the water in the reſervoir, above the pipes, was ſometimes one foot, and ſometimes two.

The following table ſhews the reſults of theſe experiments:

The conſtant height of the water in the reſervoir above the pipe, in inches.	The diſtance to which the water was conveyed, expreſſed in feet.	The number of cubic inches of water furniſhed in one minute, by a pipe of an inch and a quarter diameter.	The number of cubic inches of water furniſhed in one minute by a pipe of two inches diameter.
1	30	2778	7680
1	60	1957	5564
1	90	1587	4534
1	120	1351	3944
1	150	1178	3486
1	180	1052	3119
2	30	4066	11219
2	60	2888	8190
2	90	2352	6812
2	120	2011	5885
2	150	1762	5232
2	180	1583	4710

If, by the aid of the table of additional pipes, which has been before inſerted, we ſhould wiſh to find the quantity of water diſcharged by two additional pipes of one inch and one-third and two inches diameter, under the ſame height of the reſervoir, and without having any regard to friction, but only to the areas of the orifices of the pipes, it will be found, that during one minute,

1. The height of the reſervoir being one foot, the pipe of one inch and one-third diameter, in this caſe there will be diſcharged ſix thouſand two hundred and ninety-two cubic inches of water.

2. The height of the reſervoir being two feet, the ſame pipe will furniſh eight thouſand eight hundred and ninety-three cubic inches of water.

3. The height of the reſervoir being one foot, and the pipe two inches in diameter, there will be diſcharged fourteen thouſand one hundred and fifty-ſix cubic inches of water.

4. The height of the reſervoir being two feet, the ſame pipe will furniſh twenty thouſand and eight cubic inches of water.

It is eaſy to perceive, that theſe quantities of water are much greater than the correſponding quantities in the above table; and that the quantity furniſhed by each pipe diminiſhes, in fact, in proportion to its length, becauſe there is then a greater ſurface of friction. But it muſt be remarked, that the diminution of the quantity of water diſcharged is not exactly in proportion to the length of the pipe. The diſcharge is indeed diminiſhed as the pipe is made longer; but this diminution decreaſes (if I may uſe the expreſſion) in the progreſs of the current; for the firſt thirty feet the diſcharge is diminiſhed much more than in the ſecond thirty feet; and the third augmentation of thirty feet to the length diminiſhes the diſcharge ſtill leſs than the ſecond; and ſo of the reſt. The reſult of all this is, that in common practice, where great preciſion is not required, it may be laid down as a rule, that the quantities of water diſcharged in equal times, through the ſame horizontal pipe, under the ſame height of the reſervoir, and at different diſtances from the ſource or reſervoir, are to each other nearly in an inverſe proportion of the ſquare roots of theſe diſtances.

It may be obſerved from the preceding table, that a pipe of one inch and one-third diameter furniſhes leſs water in proportion than one of two inches diameter, under the ſame height of the reſervoir, and of the ſame length. The reaſon of this is, becauſe there is, relatively to the quantities of water which theſe pipes will contain, more ſurface of friction in the ſmall pipe than in the larger one.

If the ſame pipe was curvilinear inſtead of being ſtrait, the diſcharge would ſtill be diminiſhed from this circumſtance, though not in any conſiderable degree; but the diminution would be ſtill greater if the curvilinear pipe was placed in a vertical inſtead of a horizontal poſition. The diminution (ſmall as it is) is produced by the reſiſtance which the water meets in running againſt the angles of the pipe, which deprive it of a part of its velocity.

But if the pipe, inſtead of being curvilinear, was angular in ſeveral points, the diminution would be greater, and the more ſo in proportion as thoſe angles ſhould be more acute, becauſe then the reſiſtance to the water would be more direct. When the pipes are curved, and their curvature vertical, as in Plate X. Fig. 1. there are then declivities and aſcents in which the air will lodge, and reſiſt or even impede the courſe of the water. For example, let A B C D E F G be a pipe, the upper extremity of which A anſwers to a reſervoir which ſupplies it with water, and the extremity G goes to furniſh a fountain. The pipe being filled with nothing but air, and water being made to run from A, this water will drive the air before it, and fill the portion of the pipe A B more than the portion B C; the water having arrived at the bending C, will flow down the lower part of this bending, and will proceed to fill the bending D, leaving behind it the column of air C D, which cannot eſcape. The water, continuing to run, will riſe from D to E, and having arrived there, it will ſtill flow down the lower part of this declivity to fill the bent F, leaving behind it a ſecond column of air E F, which will remain confined there, notwithſtanding the preſſure of the column A B; for the column of air C D cannot counterbalance the preſſure of the column of water D E, any more than the column of air E F is capable of counterbalancing the column of water F I; ſo that though the water in the pipe A B is conſiderably above the level G, the water can only riſe towards I, and there ceaſes to flow. The only remedy is, to let out the two columns of air CD and E F, by placing at the elbow of the bendings two ſmall pipes C and E, through which the air may eſcape, and when the courſe of the water is well arranged the apertures may be cloſed with bungs.

VI. Of the oſcillatory motion of water in a ſiphon.

It is well known that the duration of the oſcillations of two pendulums of unequal lengths are to each other as the ſquare roots of thoſe lengths. The oſcillatory motion of water in a ſiphon is of the ſame nature.

Suppoſe a ſiphon (Fig. 2.) compoſed of three branches, two verticle *l n*, *m o*, and one horizontal *n o*; ſuppoſe that the interior diameter of the ſiphon is equal through its whole extent; that in this ſiphon, the fluid, in a ſtate of reſt, occupies the ſpace *a n o d*; then the two ſurfaces *a b*, *c d*, are upon a level. Suppoſe then, that, by ſome cauſe, the liquid is forced to deſcend to *g h*, in the branch *m o*, and conſequently to elevate itſelf to *e f*, in the branch *l n*; as ſoon as this cauſe ceaſes to act, the fluid will be operated upon merely by the common laws of gravitation and motion. The exceſs of the length of the column *e n*, above that of the column *h o*, will force the fluid to deſcend, and that even below the level of the other, on account of the acceleration of its deſcent, which will cauſe the fluid in the other branch *m o* to riſe; the fluid will then deſcend and aſcend alternately, or in oſcillations ſimilar to thoſe of a pendulum; and the deviation of each of theſe oſcillations will be preciſely the ſame as that of the oſcillations of a pendulum half as long as the length *p q r* of the column of the fluid.

Since the oſcillations of water follow the ſame law as thoſe of a pendulum, it follows, that if the length of the column of water is augmented or diminiſhed, the duration of each oſcillation will be augmented or diminiſhed.

VII. The oſcillatory motion of water in waves has been compared by Sir Iſaac Newton* to the oſcillatory motion of water in a ſiphon.

Let A B C D E F (Fig. 3.) be ſuppoſed a ſheet of water, the ſurface of which riſes and falls in ſucceſſive waves; let A C E be the tops of theſe waves, and B D F the intermediate hollows or concavities, which ſeparate them. As the waves are formed by the ſucceſſive aſcent and deſcent of the water in ſuch a manner that the higher parts become the lower, and ſo alternately and ſucceſſively, and as the weight of the elevated water is the moving power which cauſes the loweſt parts to aſcend and the higheſt to deſcend, theſe alternate riſings and fallings are conſidered as analogous to the oſcillatory motion of water in a ſiphon, and they obſerve the ſame laws relative to their duration.

If there is then a pendulum, the length of which is equal to half the tranſverſal diſtance that exiſts between the top or apex of a wave A (for example) and the cavity B, that is equal to half A *b*, the higheſt parts will become the loweſt in the ſame ſpace of time in which this pendulum vibrates, and in the ſpace of another oſcillation they will again become the higheſt. Each of theſe waves then will roll its whole courſe during the time which the pendulum takes in performing two oſcillations; and as a pendulum four times the length of the preceding, that is, the length of which is equal to the width of the wave A C, will make only one oſcillation, while the firſt makes two, it follows, that the waves perform their oſcillations in the ſame ſpace of time as a pendulum equal in length to the width of the ſame waves would perform its oſcillations. What is meant by the width of waves, is the tranſverſal ſpace A C, which is between their greateſt elevations, or the ſpace B D, which is between their greateſt concavities.

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* Principia, lib. 2. prop. 46.

It follows from theſe premiſes, that waves, which are about three feet and three quarters of an inch wide, roll their whole width during a ſecond of time, and conſequently they roll one hundred and eighty-three feet ſix inches and five-ſixths in a minute, and in an hour eleven thouſand and fourteen feet two inches; waves four times as wide will roll this ſpace in twice the time; it follows then, that the wider or more expanded the waves are, the greater will be the ſpace which they will roll over in a given time.

But what has now been ſtated reſpecting the motion of waves, is founded upon this hypotheſis, that all the parts of the water riſe and fall in right lines; yet it muſt be obſerved, that both their riſe and fall are more frequently made in curved lines than in ſtrait ones; ſo that the determination given above reſpecting the ſpace which waves roll over in a given time may be regarded only as an approximation to the truth.

VIII. The motion of wheels acted upon by the fall or force of water, though ſtrictly a branch of mechanics, is yet intimately connected with the ſcience of hydraulics.

The wheels of ſome water-mills are furniſhed with wings, float-boards, or ſhelves, at their circumference, with very little or no concavity; others are furniſhed with a kind of ladles or boxes, which will contain a conſiderable quantity of water. In the firſt caſe, the water acts upon the wheels principally by its ſhock or fall; in the ſecond, by its weight. I ſhall firſt ſpeak of wheels moved by the ſhocks of the water.

It has been proved by experience, that the more numerous the wings or float-boards are in proportion to the diameter of the wheel, the faſter it moves. To wheels of twenty feet diameter, there are commonly placed about forty float-boards; but a greater number, as for example forty-eight, would be ſtill more advantageous. To the wheels of thoſe mills which are raiſed upon boats or rafts in rivers, there are uſually only eight or ten floats; but theſe wheels would have more effect if they had fifteen or ſixteen.

When a wheel with wings or float-boards turns in a kind of frame or caſe, ſo as to prevent the water from falling immediately into the general current, the impulſe which it receives from the water is about one-fifth greater in proportion to the velocity of the fluid, than it would receive in an unconfined ſtream, becauſe in the latter caſe the water which abounds is turned behind the float, and reſiſts it; on the contrary, when the wheel moves in a frame, there is only a ſmall quantity of water, which moves with as much velocity, or with rather more, than the float-board.

It has been proved by experience, that when this caſe or frame is but juſt wide and deep enough to admit the wheel to move freely, and the water has an opportunity of running out after having given its ſhock or impulſe, the direct and perpendicular force againſt the floats of the wheel is about twice the force which the float would receive if it was plunged to the ſame depth in an unconfined current.

When a wheel furniſhed with forty-eight floats turns in a caſe or frame, and it is not plunged very deep in the water, its circumference will have about two-fifths of the velocity of the current, in which caſe the machine will produce the greateſt effect.

It appears that float-boards are the moſt advantageous when they are placed in a direct line towards the center of the wheel; becauſe but few of them would be required, ſince they would then be ſtruck perpendicularly by the water, which produces the moſt powerful effect. When they incline, the ſhock is oblique, which diminiſhes the effort; yet a certain degree of inclination cauſes the water to riſe the length of the float, and to remain there a certain time; it then acts by its gravity after having acted by its ſhock or fall, and the effect which reſults from this arrangement more than compenſates for the diminution which the ſhock ſuffered from the obliquity with which the force was applied in the firſt inſtance. In general, the wheels placed in frames which have a certain declivity ſhould have their floats or buckets inclined ſo much towards the radius as to cauſe them to be ſtruck in a more perpendicular direction, that they may receive an augmentation of force from the weight of the water. The moſt advantageous inclination of the floats towards the radius appears by experience to be between twenty and thirty degrees.

A wheel placed near a reſervoir turns ſwifter than in any other place, becauſe then the whole force of the deſcending fluid is effectually applied; but if there is a neceſſity for placing it at the end of the water-courſe, at a certain diſtance from the reſervoir, the channel of the water-courſe or frame ſhould incline about the tenth part of its length, ſo that the ſloping may give to the water that degree of velocity which would otherwiſe be deſtroyed by friction; the wheel will then receive the ſame impulſe as if it was placed cloſe to the reſervoir.

Water acting by its weight produces a much greater effect than when it acts by its ſhock in falling. M. Parent, in the year 1704, and M. Pitot, in 1725, indeed demonſtrated, that a wheel (ſuppoſed to be without friction) moved by a current of water, and deſigned to elevate a portion of that water to the height of that which puts it in motion, is incapable of elevating it higher than $\frac{4}{27}$ or $\frac{1}{7}$ nearly; whereas the water acting upon the wheel by its own weight would be capable of elevating to the height from which it deſcended half of the water which deſcended.

When, therefore, we have only a ſmall quantity of water, and are obliged to huſband it well (which often happens, becauſe there are more ſmall ſtreams than large rivers) we ſhould contrive to make this water act by its weight rather than by its ſhock or impulſe; for this purpoſe, inſtead of having wheels with plain float-boards, they ſhould be furniſhed with concave or hollow ones reſembling buckets, whenever we can have a fall of more than four feet, and eſpecially where there is not the neceſſary quantity of water to turn a mill with wheels, furniſhed with plain float-boards.

M. Deparcieux, in the Memoirs of the French Academy of Sciences *, has proved, that the ſlower wheels with buckets move, the more will be their effect with an equal expence of water. He made a ſmall wheel of twenty inches diameter, the circumference of which was furniſhed with forty-eight buckets. Upon the axis of this wheel were placed four cylinders of different ſizes; the leaſt was one inch in diameter, the next two inches, the third three inches, and the fourth was four inches in diameter. Theſe cylinders were different axes, about which a cord, which elevated a weight by means of a returning pully placed above the machine, wrapped itſelf. The axis of the wheel was ſupported at each end by two rollers eaſily put in

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* For the year 1754, page 603 and 671.

motion; this was to diminiſh the friction. To the fore part of the wheel, and a little higher than its axis, was attached a ſmall ſhelf, upon which was placed a veſſel with a hole pierced in it on that ſide towards the wheel, which was filled with water. Above this veſſel was placed a large bottle full of water inverted, and the neck of it was plunged a few lines in the water of the veſſel, in order that the bottle ſhould only empty itſelf in proportion as the water in the veſſel ran through the aperture. The water in flowing fell into a channel which carried it into the buckets of the wheel. By this means he made ſure of employing, at each experiment, always the ſame quantity of water.

The following table contains the reſults of the experiments made by M. Deparcieux. He ſometimes elevated weights of twelve ounces, and ſometimes of twenty-four ounces: the heavieſt, reſiſting the moſt, compelled the wheel to turn ſlower. He wrapped the cords which ſupported the weights ſucceſſively round the different cylinders, and found that the ſame weight reſiſted more in proportion as its cord was wrapped round a larger cylinder.

Diameter of the cylinders.	Elevation of a weight of 12 ounces.	Elevation of a weight of 24 ounces.
1 Inches.	69¾ Inches.	40
2	80½	43½
3	85½	44½
4	87¾	45¼

When the cord was wrapped round a larger cylinder, or the elevated weight was more conſiderable, the wheel turned ſlower. It appears from theſe reſults, that the ſame weight was carried ſo much higher according as its cord was wrapped round a larger cylinder. It appears alſo, that double the weight which retarded the rotation ſtill more, was carried to more than half of the height to which the ſingle weight was carried; in that caſe, therefore, the effect was greater.

It may be laid down as a principle, that water acts by its weight much more forcibly from the ſame height or fall, than by its impulſe; and that the ſlower wheels with buckets move, the greater, with the ſame expence of water, will be their effect. This augmentation of effect is cauſed by the ſame quantity of water acting longer, while the wheel moves with leſs velocity.

CHAP. IV.

OF THE OCEAN.

Saltneſs of the Ocean.—Different Opinions as to the Cauſe.—Probable Reaſons why the Sea has been always ſalt.—Temperature of the Sea at different Depths.—Modes of rendering Sea-water freſh.

THE greateſt quantities of water with which we are acquainted are by no means pure, but united with ſaline matter. The ocean is ſalt in all parts of the world; but the degree of ſaltneſs differs much in different climates, and is almoſt univerſally found to be greater in proportion as the water is taken up nearer the equator, where the heat of the ſun is greateſt, and the evaporation of the watery particles conſequently more conſiderable. When treating of ſea ſalt, the reſult of various obſervations relating to this ſubject were detailed.

The cauſe of the ſaltneſs of the ocean has been a ſubject of inveſtigation among philoſophers in almoſt all ages, but it ſtill remains in great obſcurity. There can be little doubt, that a large quantity of ſaline matter exiſted in this globe from the creation; and, at this day, we find immenſe beds of ſal gem, or common ſalt, buried in the earth, particularly near Cracow; but whether theſe collections have been derived from the ocean, and depoſited in conſequence of the evaporation of its waters in certain circumſtances, or whether the ocean was itſelf originally freſh, and received its ſalt from collections of ſaline matter ſituated at its bottom, or from that brought by the influx of rivers, cannot now be aſcertained. No accurate obſervations on the degree of ſaltneſs of the ocean in particular latitudes were made till the preſent century, and it is not poſſible, therefore, to aſcertain what was the *ſtate* of the ſea at any conſiderable diſtance of time, nor, conſequently, whether its degree of ſaltneſs increaſes, decreaſes, or is ſtationary. From differences among aquatic animals, however, ſome of which ſeem adapted to ſalt water, and ſome to freſh, it is probable, that both theſe ſtates of water exiſted from the creation of the world. We know it is true, that ſome kinds of fiſh, as ſalmon, are capable of exiſting both in freſh and in ſalt water, and that habit has a powerful influence over all animals; but this is not ſufficient to refute the main fact, that ſome kinds of fiſh thrive only in ſalt water, others in freſh; ſome in ſtanding pools, and others in rapid currents.

That excellent philoſopher and chemiſt, to whoſe labours I am indebted for ſome of the moſt valuable parts of theſe volumes, the biſhop of Landaff, has recommended a moſt ſimple and eaſy mode of aſcertaining the ſaltneſs of the ſea in any latitude; and as the language, in point of perſpicuity and correctneſs, cannot be improved, I ſhall take the liberty of inſerting it in his own words.

‘ As it is not every perſon who can make himſelf expert in the uſe of the common means of eſtimating

ing the quantity of ſalt contained in ſea water, I will mention a method of doing it, which is ſo eaſy and ſimple, that every common ſailor may underſtand and practiſe it, and which, at the ſame time, from the trials I have made of it, ſeems to be as exact a method as any that has yet been thought of.—Take a clean towel or any other piece of cloth, dry it well in the ſun or before the fire, then weigh it accurately, and note down its weight; dip it in the ſea water, and, when taken out, wring it a little till it will not drip, when hung up to dry; weigh it in this wet ſtate, then dry it either in the ſun or at the fire, and, when it is perfectly dry, weigh it again. The exceſs of the weight of the wetted cloth above its original weight, is the weight of the ſea water imbibed by the cloth; and the exceſs of the weight of the cloth, after being dried, above its original weight, is the weight of the ſalt retained by the cloth; and by comparing this weight with the weight of the ſea water imbibed by the cloth, we obtain the proportion of ſalt contained in that ſpecies of ſea water.

'Whoever undertakes to aſcertain the quantity of ſalt, contained in ſea water, either by this or any other method, would do well to obſerve the ſtate of the weather preceding the time when the ſea water is taken out of the ſea, for the quantity of ſalt contained in the water near the ſurface may be influenced both by the antecedent moiſture and the antecedent heat of the atmoſphere *.'

Whether the ſea is ſalter or not at different

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* Watſon's Chemical Eſſays, vol. ii. p. 116.

depths has not yet been aſcertained; but that its temperature varies conſiderably in proportion to the depth we have deciſive proof.

'With reſpect to the temperature,' ſays biſhop Watſon, 'of the ſea at different depths, it ſeems reaſonable enough to ſuppoſe, that in ſummer time it will be hotter at the ſurface than at any conſiderable depth below it, and that in winter it will be colder. Suppoſe a ciſtern, twelve feet in depth, to be filled with ſpring water of 48 degrees warmth, to the height of eleven feet; then, if we fill up the ciſtern to its top, by gently pouring water heated to 100 degrees upon the ſurface of the ſpring water, it may readily be underſtood, that the heat of this water will not be inſtantaneouſly communicated through the whole maſs of water in the ciſtern, but that the water will decreaſe in heat from the ſurface to the bottom of the ciſtern. On the other hand, if on the 11 feet of ſpring water heated to 48 degrees, we pour a foot of water heated only to 33 degrees, it may be expected, that the ſpring water, which is neareſt to the cold water, will be ſooner cooled by it than that which is at a greater diſtance; and on this account the water at the bottom of the ciſtern will be warmer than that in the middle or at the top. It muſt be obſerved, however, that cold water being, bulk for bulk, heavier than hot water, the water which has only 33 degrees of heat will deſcend, by its ſuperior weight, into the maſs of water contained in the ciſtern, and thus the water in the ciſtern will be cooled, not only by the bare communication of cold from the upper water, but by the actual mixture of that water with the reſt, ſo that the difference between the heat of the water at the bottom and top will not be ſo great as it would have been if the cold water had not mixed itſelf with the reſt. Theſe ſuppoſitions of hot and cold water incumbent on the ſpring water in the ciſtern, are analogous to the action of the ſummer and winter atmoſpheres incumbent on the ſurface of the ſea. No perſon, who has bathed in deep ſtanding water in ſummer time, can have failed to obſerve, that the water grew colder and colder, according to the depth to which he deſcended. I have frequently obſerved, that the ſurface of a pool of water of two feet in depth, has in a ſunny day, even in winter, been five degrees hotter than the water at its bottom.

‘ Mr. Wales deſcribes the inſtrument he made uſe of for trying the temperature of the ſea at different depths, in the following terms: “ The apparatus for trying the heat of the ſea water at different depths conſiſted of a ſquare wooden tube of about 18 inches long and three inches ſquare externally. It was fitted with a valve at the bottom, and another at the top, and had a contrivance for ſuſpending the thermometer exactly in the middle of it. When it was uſed it was faſtened to the deep ſea line, juſt above the lead, ſo that all the way as it deſcended the water had a free paſſage through it, by means of the valves which were then both open; but the inſtant it began to be drawn up, both the valves cloſed by the preſſure of the water, and of courſe the thermometer was brought up in a body of water of the ſame temperature with that it was let down to*." With this inſtrument, which is much the ſame with one formerly deſcribed by Mr. Boyle, in his obſervations about the ſaltneſs of the ſea, water was fetched up from different depths, and its temperature accurately noticed, in different ſeaſons and latitudes.

'August 27, 1772, ſouth latitude 24°. 40′. The heat of the air was 72½,—of the water at the ſurface 70,—of water from the depth of 80 fathoms 68 †.

'December 27, 1772, ſouth latitude 58°. 21′. The heat of the air was 31 ,—of the water at the ſurface 32,—of water from the depth of 160 fathoms 33½ ‡.

'In the voyage to the high northern latitudes before mentioned, they made uſe of a bottle to bring up water from the bottom, which is thus deſcribed. "The bottle had a coating of wool, three inches thick, which was wrapped up in an oiled ſkin, and let into a leather purſe, and the whole incloſed in a well-pitched canvas bag, firmly tied to the mouth of the bottle, ſo that not a drop of water could penetrate to its ſurface. A bit of lead ſhaped like a cone, with its baſe downwards,

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[*] See Aſtronomical Obſervations made in a Voyage towards the South Pole, &c. in 1772, 1773, &c. by W. Wales. Introduction, p. 53.

[†] Wales' Obſer. p. 206.

[‡] Ibid. p. 208.

and a cord fixed to its ſmall end, was put into the bottle; and a piece of valve leather, with half a dozen ſlips of thin bladder, were ſtrung on the cord, which, when pulled, effectually corked the bottle on the inſide.". I have here put down two of the experiments which were made during that voyage.

'August 4, 1773, north latitude 80°. 30′. The heat of the air was 32,—of the water at the ſurface 36,—of water fetched up from the depth of 60 fathoms under the ice 39*.

'September 4, 1773, north latitude 65°. The heat of the air was 66½,—of the water at the ſurface 55,—of water from the depth of 683 fathoms 40.

'It appears from all theſe experiments that, when the atmoſphere was hotter than the ſurface of the ſea, the ſuperficial water was hotter than that at a great depth; and when the atmoſphere was colder than the ſurface of the ſea, it is evident that the ſuperficial water was ſomewhat colder than that at a conſiderable diſtance below it: and I doubt not that this will generally be the caſe, though ſudden changes in the temperature of the atmoſphere, which cannot be inſtantly communicated to the ſea, may occaſion particular exceptions.

'In the year 1779, ſeveral experiments were made, with great accuracy, in order to inveſtigate the temperature of the lake of Geneva, and of other lakes in Switzerland, at different depths; we learn from them, that in winter time there is very little difference between the heat of the water at the ſurface, and at a great depth below it; but that in ſummer, the ſuperficial water is conſiderablv warmer than that which is at a great diſtance from the ſurface. The experiments were made with a thermometer graduated after Reaumur's ſcale; ſome of them, reduced to Fahrenheit's ſcale, are expreſſed below.

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* Voyage towards the North Pole, p. 143.

'Temperature of the lake of Geneva at different depths, in the beginning of February 1779, after a month's uninterrupted froſt.

'Heat of the open air variable from 37 to 40 degrees.

'Water at the ſurface of the lake	$42\frac{1}{8}$
Depth 100 feet	$42\frac{1}{8}$
Depth 250 feet	$42\frac{1}{8}$
Depth 950 feet bottom	$41\frac{27}{80}$

'In another part of the lake, open air from 37 to 40.

Surface	$42\frac{1}{8}$
Depth 350 feet	$42\frac{1}{8}$
Depth 620 feet, bottom	$41\frac{27}{80}$

'Temperature of the lake of Neuchâtel, July 17, 1779.

Air	$75\frac{1}{5}$
Surface	$73\frac{5}{8}$
Depth 225 feet, bottom	41*.'

Sea water may be rendered freſh by freezing, which excludes or precipitates the ſaline particles, or by diſtillation, which leaves the ſalt in a maſs at the bottom of the veſſel. Upon theſe principles, a mode of obtaining a ſupply of freſh water at ſea was recommended ſome years ago to the Admiralty, by Dr. Irving. It conſiſted in only adapting a tin tube of ſuitable dimenſions to the lid of the common ſhip's kettle, and condenſing the ſteam in a hogſhead which ſerved as a receiver. By this mode a ſupply of twenty-five gallons of freſh water per hour might be obtained from the kettle of one of our ſhips of war. I have not underſtood, however, that the plan has been as yet introduced into general practice.

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* Watſon's Chemical Eſſays, vol. ii. p. 129.

CHAP. V.

OF RAIN.

Recapitulation of Doctrines relative to ſpontaneous Evaporation.—Vapour by ſome ſuppoſed to conſiſt of hollow Veſicles.—Rain.—Different Theories of Rain.—Snow.—Hail.—Rain which froze in coming in contact with the Earth.—Large Hail-ſtones.—Fogs.—Dew.—Hoar-froſt.—Inſtances of partial freezing when the general Temperature is above the freezing Point.

IN a preceding volume, when treating of the effects of heat or fire, and particularly of vapour, it was neceſſary to introduce a few obſervations relative to ſpontaneous evaporation. It is proper, however, to repeat, in this place, that philoſophers are by no means agreed with reſpect to the cauſe of this phenomenon. By ſome it has been attributed to a ſolution of water in air ſimilar to that of ſaline ſubſtances in water; by others, to the action of the electric fluid. The firſt of theſe opinions had till lately obtained almoſt univerſal aſſent, but is now relinquiſhed, ſince it is found that evaporation proceeds, as well in the exhauſted receiver of the air pump, as when air is preſent. Electricity has been found to promote evaporation, and clouds are almoſt univerſally electrical; but evaporation is carried on continually where there is no reaſon to ſuppoſe the preſence of the electric fluid, at leaſt where its operation cannot be diſcovered by any known teſt. It is at preſent commonly ſuppoſed, that redundant heat is the general cauſe of the evaporation of water, and that it always proceeds in proportion to its temperature, compared with that of the ſurrounding medium.

There is one circumſtance very much in favour of the opinion, that the emiſſion of heat is the chief cauſe of evaporation, which is, that every liquor cools when it evaporates, becauſe the portion of the fluid which diſappears carries away a quantity of caloric from the liquor, which becomes latent in the vapour.

A doubt has ariſen among philoſophers, whether water, as it exiſts in a tranſparent ſtate in the atmoſphere, is in particles of an uniform denſity, or aſſumes the form of hollow veſicles. When there is a tendency to rain or ſnow, it is known to exiſt in the ſtate of minute drops and icicles; but the ſolution is then not perfect, its tranſparency is impaired, and clouds are produced.

The exiſtence of hollow ſpheres is ſaid to have been actually obſerved by ſeveral perſons; but as a microſcope of conſiderable magnifying power muſt be employed, this may have been a ſource of error, and may have produced deluſive appearances. The ſimpleſt and moſt inſtructive manner of obſerving them is to expoſe a cup of ſome warm aqueous fluid, of a dark colour, as coffee, or water mixed with ink, to the rays of the ſun in a fine day, when the air is very calm; a cloud will riſe from the fluid to a certain height, and then diſappear. An attentive eye will ſoon diſcover that this cloud conſiſts of ſmall round grains, of a whitiſh colour, and detached one from the other. To acquire a more diſtinct idea of their form, they may be obſerved, as they riſe from the ſurface of the liquor, with a lens of about one inch and an half focus, being careful, however, to keep the lens out of the vapours, that they may not deprive it of tranſparency.

Spherical balls of different ſizes may in this manner be obſerved proceeding from the ſurface with more or leſs rapidity. The more delicate riſe ſwiftly, and ſoon traverſe the field of the lens; the larger fall back into the cup, and, without mixing with the fluid, roll upon its ſurface like a light powder, which obeys every impulſe of the air. The lightneſs of theſe ſmall ſpheres, their whiteneſs, &c. give them an appearance altogether different from ſolid globules; their perfect reſemblance to the larger balls, that are ſeen floating on the ſurface of the liquid, can leave no doubt of their nature; it is ſufficient to ſee them to be convinced that they are hollow bubbles, like thoſe blown from water and ſoap. M. Kratzenſtein endeavoured to eſtimate their ſize, by comparing them with a hair, and found that they were twelve times ſmaller than the hair, the diameter of which was the three hundredth part of an inch, and conſequently one of theſe was only the three thouſand ſix hundredth part of the ſame meaſure.

Theſe bubbles may even be ſometimes, it is ſaid, obſerved in a fog, or in a cloud, when the obſerver is ſituated on a hill. To this end M. de Sauſſure uſed a lens of one and an half or two inches focus, which he held near his eye with one hand, in the other he held any ſmooth, flat, and poliſhed ſurface, of a black colour, as the bottom of a tortoiſe ſhell box, bringing this towards the lens till it was very near the focal diſtance; he then waited till the agitation of the air brought ſome particles of the cloud into the focus of the lens; when the cloud was thick this ſoon happened, and he perceived round and white particles, ſome paſſing with the rapidity of lightning, others moving ſlowly; ſome rolling on the ſurface of the tortoiſe ſhell, others ſtriking againſt it obliquely, and rebounding like a ball from a wall, and others fixing themſelves to it. Small drops of water might alſo be ſeen to ſettle on the tortoiſe ſhell, but they were eaſily diſtinguiſhed from the hollow ſpherules, by their tranſparency, their gravity, and their pace, Further, clouds do not form a rainbow; it is produced by ſolid drops; when a cloud is not in an actual ſtate of reſolution, it does not change the form of the ſtars which are ſeen through it; for infinitely thin meniſcuſſes do not ſenſibly change the courſe of the rays of light; but as ſoon as the cloud begins to reſolve itſelf into ſolid drops, or even without clouds, when ſolid drops begin to be formed in the air, the ſtars ſeen through them are all defined, ſurrounded with a diffuſe light, circles, and halos; hence, theſe meteors are the forerunners of rain, for rain is nothing more than theſe drops augmented or united. When the veſicular vapours are condenſed by cold, the water which formed the bubble cryſtallizes, ſometimes into hoar froſt, ſometimes into ſnow; when it does not freeze, they unite in dew, or deſcend in rain. Many other curious properties concerning the veſicular and concrete vapours are related in M. de Sauſſure's Eſſai ſur l' Hygrometrie*.

The precipitation of water from the atmoſphere, in rain has given riſe to as much ſpeculation as evaporation; and it muſt be confeſſed, that the cauſe of neither has yet been very clearly aſcertained. By ſome it is ſuppoſed, that the capacity of the air for ſuſpending aqueous vapour is in proportion to its heat, and therefore that any circumſtance which cools the atmoſphere will produce rain. If, therefore, according to this theory, a ſtratum of cold air meets with a warmer ſtratum, a fall of rain is occaſioned, becauſe the warmer ſtratum is cooled. To this it has been replied, that by this mixture the colder ſtratum muſt be as much warmed as the warmer is cooled, and, therefore, that no precipitation ought to take place. In order to obviate this difficulty, Dr. Hutton ſuppoſes that heat enables the atmoſphere to ſuſpend water in an increaſing ratio, according to the quantity of it. Thus, if two degrees of heat enable a certain quantity of air to ſuſpend two given meaſures of water, three degrees of heat will enable the ſame quantity of air to ſuſpend more than three ſuch meaſures. Upon this ſuppoſition, if two ſtrata of air, each of which is charged with as much water as its temperature enables it to ſuſpend, meet together, and are reduced to a mean temperature; they will not be able to ſuſpend as much water as in their ſeparate ſtate, and a precipitation of part of the water will conſequently be produced *.

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* See Adams's Lectures on Natural Philoſophy.

Others conſider rain as an electrical phenomenon †, and it is very generally allowed, that electricity at leaſt concurs with other cauſes in producing it. Bodies charged with the ſame electricity, whether it is negative or poſitive, always repel each other, and the aqueous particles which compoſe clouds, being acted on in this way, will be prevented from uniting into drops ſufficiently large to fall to the earth. The rapidity with which rain falls after a diſcharge of lightning from a cloud, tends much to confirm this opinion. Rain alſo falls heavieſt from the center of a cloud, where the electric matter has been found by experiment to be generally in equilibrio; while very little is diſcharged from the edges, which are uſually found to be electrified either poſitively or negatively.

The wind has been ſuppoſed to have an effect in producing rain, by driving the aqueous particles into contact, and thus cauſing them to unite into drops. But, by experience, wind ſeems to have

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* That heat has a conſiderable influence in ſuſpending aqueous vapour, appears from the phenomenon of dew; which, the reader will remember, is part of the water taken up by the air during the day time, but which is again depoſited during the coolneſs of the night.

† See Book IV. chap. 6.

the direct contrary influence, and frequently prevents rain.

Beſides rain, many other phenomena are produced by the capacity which air has in different circumſtances of taking up, ſuſpending, and depoſiting water; the chief of theſe are ſnow, hail, fogs, clouds, dew, and hoar froſt.

The cold of the higher regions of the atmoſphere is ſometimes ſo great, as to freeze the aqueous particles which form clouds. If the particles become frozen before they have had time to unite into drops, many of the ſmall icicles which are produced, uniting together, and being connected only at a few points, form flocculent maſſes, which are called ſnow. The order and arrangement of the icicles is not always the ſame; they vary greatly, and this produces the variety which is obſerved in ſnow. It is remarkable, that though ſnow varies at different times, yet what falls together is always the ſame; that is, the ſnow which falls at a particular time, conſiſts of flakes, which vary only in ſize, but are all formed of particles diſpoſed in a ſimilar manner. We are not ſufficiently acquainted with the laws by which the concretion or cryſtallization of bodies are regulated, to explain the cauſe of theſe phenomena. On account of the ſmall quantity of matter contained in ſnow, in proportion to the ſurfaces expoſed, it meets with great reſiſtance in paſſing through the atmoſphere, and conſequently falls very ſlowly. Its great ſurface alſo renders it very ſuſceptible of evaporation, which conſiderably diminiſhes its weight even in the coldeſt weather.

If the cold is ſo moderate, as to allow the particles of water to unite into drops before congelation takes place, particles of ice are produced, which are called hail. The ſame thing may be ſuppoſed to happen when the lower regions of the atmoſphere are colder than the upper, which, though contrary to the general courſe of things, ſometimes happens. In ſuch a caſe, the aqueous particles, after having united above into rain, are congealed in their deſcent, and are converted into hail. In the year 1775 or 1776, rain fell at Liverpool, which became ſolid as ſoon as it reached the ſurface of the earth, in ſuch a manner as to give a covering of ice to whatever was wet with it, and even to form icicles on the dreſs of perſons expoſed to it. This phenomenon I have alſo witneſſed elſewhere.

Hail, when firſt formed, muſt be perfectly round, becauſe formed from a fluid; and all fluids, when placed in ſuch ſituations as to receive an equal preſſure in every direction from the medium which ſurrounds them, naturally aſſume a ſpherical form. Hail, however, when it arrives at the earth is often angular; this muſt be explained, either by ſuppoſing that the particles have begun to diſſolve, or that they were ſufficiently cold to congeal and attach to their ſurface, the aqueous particles with which they came into contact in their fall. Hail, when firſt formed, is never larger than the drops of water which fall in rain; but from the cauſe juſt mentioned, hail-ſtones have ſometimes been known

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to fall as large as nuts, or even as hens' eggs. In order to convince ourſelves, that ſuch hail-ſtones owe their extraordinary ſize to the additions which they receive in falling, it is only neceſſary to examine them: they will almoſt uniformly be found to be angular, and never to have an uniform denſity from the circumference to the center, which clearly proves, that they are compoſed of different particles of ice connected together. In confirmation of the ſame opinion, it is obſerved, that the hail which falls on mountains, is ſmaller than that which deſcends in the neighbouring vallies. The ſame obſervation has been repeatedly made with reſpect to rain, by perſons in the habit of aſcending mountains, for the purpoſe of philoſophical experiment.

It ſometimes happens from the ſtate of the atmoſphere, or a concurrence of circumſtances not eaſily to be aſcertained, that a great quantity of aqueous particles are raiſed in the atmoſphere, where, being incompletely diſſolved, they form a thick vapour, which extends itſelf in the lower part of the atmoſphere; theſe particles, deſtroying the tranſparency of the atmoſphere, form fogs. Fogs are more frequent in low, wet, and marſhy ſituations, near rivers and ponds, than in ſuch parts of a country as are elevated and dry. It ſometimes happens, that certain exhalations are mixed with fogs, which are perceived by their unpleaſant ſmell, and by an acute ſenſation which is felt by the throat and eyes.

Fogs are much more frequent in cold ſeaſons, and in cold climates, than in ſuch as are warm, becauſe in the former, the aqueous particles being condenſed almoſt as ſoon as they proceed from the ſurface of the earth, are incapable of riſing into the higher parts of the atmoſphere. If the cold is augmented, the fog freezes and attaches itſelf in ſmall icicles to the branches of trees, to the hair and clothes of perſons expoſed to it, to the blades of graſs, &c.

When fogs riſe to a conſiderable height in the atmoſphere, and are collected in a denſe ſtate, whether this happens from any action of the air or from other cauſes, they form clouds, which float in different regions of the atmoſphere according to their ſpecific gravity; ſince they neceſſarily riſe or fall, till they arrive at that part of the atmoſphere which is in equilibrium with themſelves. As the atmoſphere is heavieſt below, denſe and thick clouds, which are at the point of uniting into rain, float near the ſurface of the earth, while the fleecy and thin clouds ſoar aloft. We often obſerve both kinds at different heights in the atmoſphere at the ſame time. As clouds are formed of water, they are moſt copiouſly produced where the air has moſt opportunity of acting on that fluid. Conſequently winds which blow from the weſt and ſouthweſt, from the atlantic ocean, bring more clouds to this country than eaſterly winds, which only paſs over a narrow channel of the ſea.

During the day time the ſun heats the earth, water, air, and every thing which is expoſed to its rays. The heat communicated to all theſe bodies is diminiſhed after ſun ſet, but the air is more ſuddenly cooled than the more ſolid bodies. Heat, therefore, which has always a diſpoſition to diſtribute itſelf equally, paſſes from the ſurface of water and earth into the air, and carries with it ſome aqueous particles, which are ſuſpended near the ſurface. When the cold increaſes during the night, theſe vapours are condenſed, and occaſion that dampneſs which is felt on the clothes of perſons expoſed to the night air, and form that dew which is ſo refreſhing to vegetables ſcorched during the day time by the ſummer's ſun.

In cold weather the dew becomes frozen into hoar froſt, for the formation of which it is not neceſſary that the earth, or even the air, ſhould be ſo far cooled as to occaſion the congelation of water into ice. This fact can only be explained, by conſidering that theſe ſmall drops of water expoſe a large ſurface to the action of the air; and by this means evaporation, which powerfully produces cold, is promoted. For the ſame reaſon clothes hung out to dry, are frequently frozen ſtiff, when no ice is formed in water expoſed to the ſame degree of cold, but in circumſtances leſs favourable to evaporation.

CHAP. VI.

OF SPRINGS AND RIVERS:

Origin of Springs.—Digging of Wells.—Nature of Springs.—Marſhes.—Cheap and eaſy Mode of draining them.—Intermitting Springs.—Rivers.—Their Source, &c.

THE water which falls on the ſurface of the earth, in rain, ſnow, &c. penetrates its ſubſtance till it meets with a ſtratum of clay, ſtone, or ſome other matter which ſtops its deſcent; it then glides laterally on the ſtratum which ſuſtains it, and in the direction to which it leans, till meeting with an aperture, it appears on the ſurface of the earth in the form of a ſpring. As water always has a tendency to deſcend, ſprings are always lower than the ſource from which they are ſupplied; ſprings are moſt common on the ſides and at the bottom of mountains; they are ſeldom found quite at the ſummit of a mountain, and are rare where a country is every where level to a conſiderable diſtance, becauſe there the ſtrata are parallel, and do not conduct the water to any particular point. In order to obtain water, therefore, in flat countries, it is in general neceſſary to dig into the earth, when it is found to flow copiouſly from the ſides of the opening, at no great diſtance from the ſurface. When wells are dug in elevated ſituations, water is ſeldom met with till we have dug to a conſiderable depth, and got below the general level of the country.

A curious circumſtance occurs in the making of wells at Modena and Stiria in Italy. The workmen begin by digging through ſeveral ſtrata or ſoils, till they come to a very hard kind of earth much reſembling chalk; here they begin their maſon-work, and build a well, which they carry on at their leiſure till they have finiſhed it, without being interrupted with one drop of water, and without any apprehenſion of not finding it when they come to make the experiment. The well being finiſhed, they bore through the hard bed of chalk, upon which the well is built, with a long auger, but take care to get out of the well before they draw it out again; which when they have done, the water ſprings up into the well, and in a little time riſes to the brim, nay ſometimes overflows the neighbouring grounds. Now there can be little doubt, that theſe waters flow from reſervoirs which are collected within the Appennine mountains, not far from Modena, and taking their courſe through ſubterraneous paſſages, endeavour to force their aſcent to the ſame height from which they deſcend, whereever they can find a vent.

As all the water which falls in rain has undergone a natural diſtillation, it is much more pure when it firſt falls, than after it has paſſed through different ſtrata of the earth and riſes in ſprings. Spring water is always found to contain ſome foreign admixture; if this ſhould be only an earthy ſalt, the water is called hard; if it contains other ſubſtances, it then receives the denomination of mineral water;

but theſe will require to be treated of in a diſtinct chapter.

The water which lies upon marſhes and ſwampy grounds, has generally its ſource in ſome ſpring, which is placed above the level of the marſh. The ſoil, therefore, in thoſe places, being generally of a ſpongy texture imbibes the water, and permits it to diſperſe through its whole maſs, rather than force its way through a certain aperture; and as marſh-lands are commonly level, the water will be more eaſily diffuſed through the ſoil, than it can be upon the declivity of a hill. The great art, therefore, in the draining of marſhes is to diſcover the ſource, which may be looked for on the brow of ſome eminence which overhangs them; and it may generally be found by obſerving where the boggy part grows narrow and angular, and points as to an apex, which is the ſpring whence all the miſchief proceeds. When the ſource is once diſcovered, the water may be eaſily drawn off by drains, aqueducts, or pipes, according to the circumſtances of the caſe. The common mode of draining land by cutting deep trenches, or drains, through the marſh itſelf, to ſerve as reſervoirs for the water, is much more laborious and expenſive, and indeed ſeldom anſwers the end propoſed; for as ſoon as the trenches fill, the ground is rendered as ſwampy as ever; and even where drains are made on the principle of an inclined plain to draw off the water, they are frequently ſtopped by the mud of the marſh, and the leaſt ſtoppage expoſes the land again to at leaſt a partial overflow.

There are ſome ſprings which exhibit a very curious phenomenon, a kind of tide or intermiſſion, by which the water at certain periods appears to riſe to a conſiderable height, and gradually to ſubſide. Theſe are called intermitting ſprings. It was long imagined, that theſe fountains were repleniſhed by ſome connection with the ſea; that the water was freſhened by its progreſs through ſand and earth, and that their riſing and falling depended on the tide. It was, however, found, that the periods of the water riſing and falling in theſe ſprings, did not correſpond in point of time with the tides of the adjacent ſeas, and that the periods were different in different ſprings, contrary to the regular riſing and falling of tides in the ocean. The phenomenon has ſince been very ſatisfactorily explained, and upon a very ſimple and obvious principle. It has been already ſhewn, that when a ſiphon is inſerted in a veſſel containing water, if the air is drawn out of the ſiphon, or by any means the water is made to flow over the bent of the tube, which lies above the brim of the veſſel, the water will continue to flow over the brim through the ſiphon till the whole is exhauſted.

To account, therefore, for the intermitting ſpring, we have only to ſuppoſe, that a cavity or receptacle is formed in the bowels of the hill or mountain, where the ſpring is ſituated, which gradually fills with water like other reſervoirs; by the interpoſition of ſome ſtratum of ſtone or rock, the tube or cavity which conveys the water from this receptacle to the ſpring or mouth where it iſſues, is bent

Fig. 1.

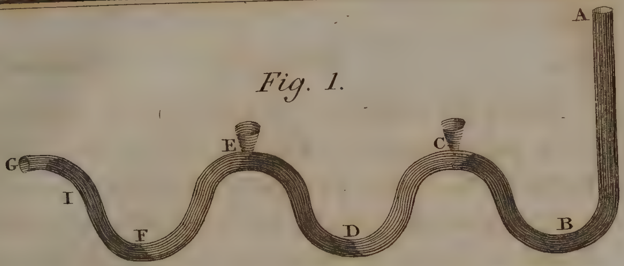


Fig. 2.

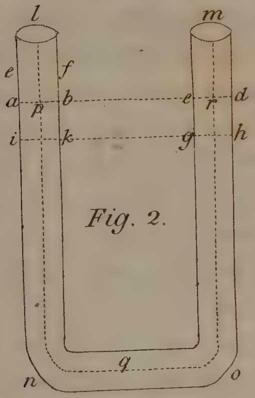


Fig. 3.

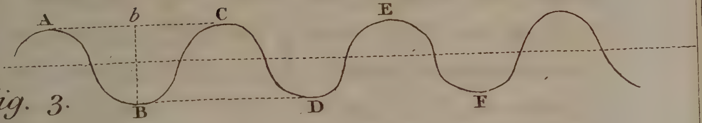
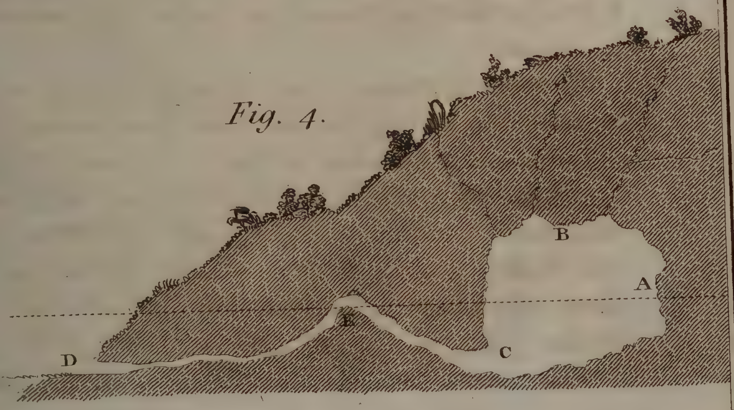


Fig. 4.



in the form of a ſiphon, the bent of which is conſiderably higher than the bottom of the reſervoir. Whenever, therefore, the reſervoir or receptacle is filled as high as the bent of the tube, the water will riſe in it to its level, and begin to flow into the ſpring, which will continue till the receptacle is exhauſted. While this proceſs is going on the water in the ſpring will riſe; and as ſoon as the receptacle is exhauſted, the water, being drawn off by a ſtream or rivulet, will appear to fall in the well of the ſpring, and will continue to fall till the receptacle is again ſupplied to the height of the ſiphon or tube, when the proceſs of filling will be again renewed.

To render the matter perfectly plain, let A B C (Plate X. Fig. 4.) repreſent the cavity or receptacle, from the bottom of which C proceeds the tube or ſiphon D E. When the water riſes in the receptacle to the level of E in the tube, it will begin to flow into the ſpring at D, on the principle explained in the preceding paragraph, and the whole phenomenon will be eaſily accounted for.

With any perſon who has carefully obſerved the courſe of rivers, and traced them to their ſources, there can be little doubt that they are formed by the confluence of ſprings, or of the little ſtreams or rivulets that iſſue from them; with perhaps the exception of thoſe rivers which proceed from lakes, where the reſervoir is ready formed, and generally by the ſame means.

In the beginning of the preſent century, the philoſophical world was agitated by a debate concerning the origin of thoſe waters which are neceſſary for the ſupply of rivers, &c. one party contended ſtrongly for the exiſtence of a large maſs of water within the bowels of the earth, which ſupplied not only the rivers but the ocean itſelf; at the head of theſe we may place the ingenious but fanciful Burnet. The French philoſophers, on the contrary, aſſerted, that the waters of the ocean were conveyed back by ſome ſubterraneous paſſages to the land, and being filtrated in their paſſage, returned again to the ſea in the courſe of the rivers; but this opinion appears contrary to all the known principles of hydroſtatics.

In oppoſition to theſe hypotheſes, our illuſtrious countryman Halley contended that the proceſs of evaporation, and the immenſe depoſition of water in conſequence of it, was fully adequate to the whole ſupply. If, indeed, we conſider the immenſe quantity of water which is continually carried up into the atmoſphere by evaporation, as ſtated in a former chapter, and conſider that this is a proceſs which is continually going on, not only from the ocean but from the rivers themſelves, and from the whole ſurface of the earth, we ſhall ſee but little reaſon to doubt of Dr. Halley's hypotheſis, but may reaſonably conclude, that this kind of circulation is carried on through all nature, and that the ſea receives back again through the channel of the rivers, that water which it parts with to the atmoſphere.

'All rivers have their ſource either in mountains, or elevated lakes; and it is in their deſcent from theſe, that they acquire that velocity which maintains their future current. At firſt their courſe is generally rapid and headlong; but it is retarded in its journey by the continual friction againſt its banks, by the many obſtacles it meets to divert its ſtream, and by the plains generally becoming more level as it approaches towards the ſea.

'Rivers, as every body has ſeen, are always broadeſt at the mouth; and grow narrower towards their ſource. But what is leſs known, and probably more deſerving curioſity, is, that they run in a more direct channel as they immediately leave their ſources; and that their ſinuoſities and turnings become more numerous as they proceed. It is a certain ſign among the ſavages of North America, that they are near the ſea, when they find the rivers winding, and every now and then changing their direction. And this is even now become an indication to the Europeans themſelves, in their journies through thoſe trackleſs foreſts. As thoſe ſinuoſities, therefore, increaſe as the river approaches the ſea, it is not to be wondered at, that they ſometimes divide, and thus diſembogue by different channels. The Danube diſembogues into the Euxine by ſeven mouths; the Nile, by the ſame number; and the Wolga, by ſeventy.

'The largeſt rivers of Europe are, firſt, the Wolga, which is about ſix hundred and fifty leagues in length, extending from Reſchow to Aſtrachan. It is remarkable of this river, that it abounds with water during the ſummer months of May and June; but all the reſt of the year is ſo ſhallow as ſcarce to cover its bottom, or allow a paſſage for loaded veſſels

ſels that trade up its ſtream. The next in order is the Danube. The courſe of this is about four hundred and fifty leagues, from the mountains of Switzerland to the Black Sea. The Don, or Tanais, which is four hundred leagues from the ſource of that branch of it called the Soſtna, to its mouth in the Euxine Sea. In one part of its courſe it approaches near the Wolga; and Peter the Great had actually begun a canal, by which he intended joining thoſe two rivers; but this he did not live to finiſh. The Nieper, or Boryſthenes, which riſes in the middle of Muſcovy, and runs the courſe of three hundred and fifty leagues, to empty itſelf into the Black Sea. The Old Coſſacks inhabit the banks and iſlands of this river; and frequently croſs the Black Sea, to plunder the maritime places on the coaſts of Turkey. The Dwina, which takes its riſe in a province of the ſame name in Ruſſia, that runs a courſe of three hundred leagues, and diſembogues into the White Sea, a little below Archangel.

‘The largeſt rivers of Aſia are, the Hohanho, in China, which is eight hundred and fifty leagues in length, computed from its ſource at Raja Ribron, to its mouth in the Gulph of Changi. The Jeniſca of Tartary, about eight hundred leagues in length, from the Lake Selinga to the Icy Sea. This river is, by ſome, ſuppoſed to ſupply moſt of that great quantity of drift wood which is ſeen floating in the ſeas, near the Artic circle. The Oby, of five hundred leagues, running from the lake of Kila into the Northern Sea. The Amour, in Eaſtern Tartary,

tary, whoſe courſe is about five hundred and ſeventy-five leagues, from its ſource to its entrance into the ſea of Kamtſchatka. The Kiam, in China, five hundred and fifty leagues in length. The Ganges, one of the moſt noted rivers in the world, and about as long as the former. It riſes in the mountains which ſeparate India from Tartary; and running through the dominions of the Great Mogul, diſcharges itſelf by ſeveral mouths into the bay of Bengal. It is not only eſteemed by the Indians for the depth, and pureneſs of its ſtream, but for a ſuppoſed ſanctity which they believe to be in its waters. It is viſited annually by ſeveral hundred thouſand pilgrims, who pay their devotions to the river as to a god; for ſavage ſimplicity is always known to miſtake the bleſſings of the deity for the deity himſelf. They carry their dying friends, from diſtant countries, to expire on its banks; and to be buried in its ſtream. The water is loweſt in April or May; but the rains beginning to fall ſoon after, the flat country is overflowed for ſeveral miles, till about the end of September; the waters then begin to retire, leaving a prolific ſediment behind, that enriches the ſoil, and, in a few days time, gives a luxuriance to vegetation, beyond what can be conceved by an European. Next to this may be reckoned the ſtill more celebrated river Euphrates. This riſes from two ſources, northward of the city Erzerum, in Turcumania; and unites about three days journey below the ſame, whence, after performing a courſe of five hundred leagues, it falls into the Gulph of Perſia, fifty miles below the city of Baſſora in Arabia. The river Indus is extended, from its ſource to its diſcharge into the Arabian ſea, four hundred leagues.

'The largeſt rivers of Africa are, the Senegal, which runs a courſe of not leſs than eleven hundred leagues, comprehending the Niger, which ſome have ſuppoſed to fall into it. However, later accounts ſeem to affirm that the Niger is loſt in the ſands, about three hundred miles up from the weſtern coaſts of Africa. Be this as it may, the Senegal is well known to be navigable for more than three hundred leagues up the country; and how much higher it may reach is not yet diſcovered, as the dreadful fatality of the inland parts of Africa, not only deter curioſity, but even avarice, which is a much ſtronger paſſion. The celebrated river Nile is ſaid to be nine hundred and ſeventy leagues, from its ſource among the mountains of the Moon, in Upper Æthiopia, to its opening into the Mediterranean Sea. Upon its arrival in the kingdom of Upper Ægypt, it runs through a rocky channel, which ſome late travellers have miſtaken for its cataracts. In the beginning of its courſe, it receives many leſſer rivers into it; and Pliny was miſtaken, in ſaying that it received none. In the beginning alſo of its courſe, it has many windings; but, for above three hundred leagues from the ſea, runs in a direct line. Its annual overflowings ariſe from a very obvious cauſe, which is almoſt univerſal with the great rivers that take their ſource near the line. The rainy ſeaſon, which is periodical in thoſe climates, floods the rivers; and as this always happens in our ſummer, ſo the Nile is at that time overflown. From theſe inundations, the inhabitants of Egypt derive happineſs and plenty; and, when the river does not arrive to its accuſtomed heights, they prepare for an indifferent harveſt. It begins to overflow about the 17th of June; it generally continues to augment for forty days, and decreaſes in about as many more. The time of increaſe and decreaſe, however, is much more inconſiderable now than it was among the ancients. Herodotus informs us, that it was an hundred days riſing, and as many falling; which ſhews that the inundation was much greater at that time than at preſent. M. Buffon * has aſcribed the preſent diminution, as well to the leſſening of the mountains of the Moon, by their ſubſtance having ſo long been waſhed down with the ſtream, as to the riſing of the earth in Egypt, that has for ſo many ages received this extraneous ſupply. But we do not find, by the buildings that have remained ſince the times of the ancients, that the earth is much raiſed ſince then. Beſides the Nile in Africa, we may reckon the Zara, and the Coanza, from the greatneſs of whoſe openings into the ſea, and the rapidity of whoſe ſtreams, we form an eſtimate of the great diſtance whence they come. Their courſes, however, are ſpent in watering deſerts and ſavage countries, whoſe poverty or fierceneſs have kept ſtrangers away.

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* Buffon, vol. ii. p. 82.

‘ But of all parts of the world, America, as it exhibits the moſt lofty mountains, ſo alſo it ſupplies the largeſt rivers. The principal of theſe is the great river Amazons, which, from its ſource in the lake of Lauricocha, to its diſcharge into the Weſtern Ocean, performs a courſe of more than twelve hundred leagues *. The breadth and depth of this river is anſwerable to its vaſt length; and, where its width is moſt contracted, its depth is augmented in proportion. So great is the body of its waters, that other rivers, though before the objects of admiration, are loſt in its boſom. It proceeds after their junction, with its uſual appearance, without any viſible change in its breadth or rapidity; and, if we may ſo expreſs it, remains great without oſtentation. In ſome places it diſplays its whole magnificence, dividing into ſeveral large branches, and encompaſſing a multitude of iſlands; and, at length, diſcharging itſelf into the ocean, by a channel of an hundred and fifty miles broad. Another river, that may almoſt rival the former, is the St. Lawrence, in Canada, which riſing in the lake Aſſiniboils, paſſes from one lake to another, from Chriſtinaux to Alempigo; and thence to lake Superior; thence to the lake Hurons; to lake Erie; to lake Ontario; and, at laſt, after a courſe of nine hundred leagues, pours their collected waters into the Atlantic ocean. The river Miſſiſſippi is more than ſeven hundred leagues in length, beginning at its ſource near the lake Aſſiniboils, and ending at its opening into the Gulph of Mexi-

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* Ulloa, vol. i. p. 388.

co. The river Plata runs a length of more than eight hundred leagues from its ſource in the river Parana, to its mouth. The river Oroonoko is ſeven hundred and fifty leagues in length, from its ſource near Paſto, to its diſcharge into the Atlantic ocean.

'Such is the amazing length of the greateſt rivers; and even in ſome of theſe, the moſt remote ſources very probably yet continue unknown. In fact, if we conſider the number of rivers which they receive, and the little acquaintance we have with the regions through which they run, it is not to be wondered at that geographers are divided concerning the ſources of moſt of them. As among a number of roots by which nouriſhment is conveyed to a ſtately tree, it is difficult to determine preciſely that by which the tree is chiefly ſupplied; ſo among the many branches of a great river, it is equally difficult to tell which is the original. Hence it may eaſily happen, that a ſimilar branch is taken for the capital ſtream; and its runnings are purſued, and delineated, in prejudice of ſome other branch that better deſerved the name and the deſcription. In this manner *, in Europe, the Danube is known to receive thirty leſſer rivers; the Wolga thirty-two or thirty-three. In Aſia, the Hohanno receives thirty-five; the Jeniſca above ſixty; the Oby as many; the Amour about forty; the Nanquin receives thirty rivers; the Ganges twenty; and the Euphrates about eleven. In Africa, the Senegal receives more than twenty rivers; the Nile receives not one for five hundred leagues upwards,

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* Buffon, vol. ii. p. 74.

and then only twelve or thirteen. In America, the river Amazons receives above ſixty, and thoſe very conſiderable; the river St. Lawrence about forty, counting thoſe which fall into its lakes; the Miſſiſſippi receives forty; and the river Plata above fifty*.'

The inundations of the Ganges and the Nile have been already mentioned, and it might be added, that almoſt all great rivers have their periodical inundations from ſimilar cauſes. The author already quoted obſerves, that, ' beſides theſe annually periodical inundations, there are many rivers that overflow at much ſhorter intervals. Thus moſt of thoſe in Peru and Chili have ſcarce any motion by night; but upon the appearance of the morning ſun they reſume their former rapidity: this proceeds from the mountain ſnows, which, melting with the heat, encreaſe the ſtream, and continue to drive on the current while the ſun continues to diſſolve them.'

There are ſome rivers which are ſaid to loſe themſelves in chaſms under the earth, and to flow for ſeveral miles in ſecret and undiſcovered channels. On this circumſtance is founded one of the moſt beautiful fables of antiquity, relative to the fountain of Arethuſa, in Sicily. The ſame thing is affirmed of the Rhine, and even of the river Mole, in Surrey, which, from this circumſtance, derives its name. With reſpect to the two latter rivers, however, ſome doubts are entertained of the fact, but theſe are rather a ſubject of inquiry to the geographer than to the natural hiſtorian.

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* Goldſmith's Earth, p. 200.

CHAP. VII.

HOT SPRINGS.

Probable Cauſes of theſe Phenomena.—Abound moſt in volcanic Regions.—Hot Springs in Iceland, near Mount Hecla.—At Geyſer.—In the Iſland of Iſchia.—At Viterbo.—Explanation of theſe Phenomena.—Burning Well in Lancaſhire.—Explained.

THERE are few objects in natural hiſtory, which preſent themſelves to our conſideration, accompanied with greater difficulties than thoſe tepid ſprings, which exiſt in different parts of the world, of different degrees of temperature, and exhibiting a variety of the moſt curious phenomena. Many of theſe have exiſted as long as the earlieſt records, and for whole centuries have exhibited little variation in their temperature.

If any circumſtance could ſerve to ſupport the very dubious hypotheſis of an immenſe reſervoir of fire in the center of the earth, it would be theſe phenomena; yet there is but little reaſon to ſuppoſe that the origin of theſe tepid ſprings lies at any vaſt depth beneath the ſurface; and, indeed, if we admit the notion of a central fire, its effect ought to be more general than it is found to be. The moſt probable hypotheſis is, therefore, that the ſame cauſes operate to produce theſe, which produce volcanoes; and the only inference to be drawn from their permanent temperature is, that the maſſes of matter, which produce volcanic eruptions, may

exiſt

exiſt for a long ſeries of time, even in a ſtate of inflammation, without burſting thoſe bandages with which nature has confined them; and that heat may long be continued to a conſiderable degree in the earth, without exhibiting to our affrighted ſenſes the formidable phenomenon of a volcanic fire.

It is, however, in volcanic regions, that tepid waters are found in the greateſt quantity; and it is in theſe that they diſplay the moſt ſtriking phenomena. At Laugervarm, a ſmall lake, two days journey from Mount Hecla, in Iceland, there are hot ſpouting ſprings, one of which throws up a column of water to the height of twenty-four feet. A piece of mutton and ſome ſalmon trout were almoſt boiled to pieces, in ſix minutes, in one of theſe ſprings. At Geyſer, in the ſame iſland, there are forty or fifty ſpouting ſprings within the compaſs of three miles; in ſome the water is impregnated with clay, and white in its appearance; in ſome, where it paſſes through a fine ochre, it is red as ſcarlet; in ſome it ſpouts forth in a continued ſtream; in others, at intervals, like an artificial jet d'eau. The largeſt which Von Troil obſerved had an aperture nineteen feet in diameter, through which the water ſpouted, at intervals, nine or ten times a day; round the top of it is a baſon, which, together with the pipe, is in the form of a caldron; the margin of the baſon is nine feet higher than the conduit, and its diameter fifty-ſix feet. The water was thrown up in an immenſe column, at different times, to the height of from thirty to ſixty feet, and at one time to the height of ninety-two feet. Previous to this exploſion the earth began to tremble in three different places, and a noiſe was heard like a battery of cannon *.

Another writer ſtates, that at Geyſer, in Iceland, there ſprings up a hot water, which, upon cooling, depoſits ſiliceous earth; and that of this very matter it has formed for itſelf a crater, in which columns of water, of a ſtupendous bulk, after they have been thrown to the height of ninety feet and upwards, fall, and are again received. The heat of the water during the exploſion cannot be meaſured; but after it has riſen and fallen through a ſtratum of air ninety feet thick, it raiſes the thermometer to 212°, which evinces that the heat in the bowels of the earth muſt be much more intenſe; and at this we ſhall ceaſe to wonder when we conſider, that in this caſe the ſubterraneous fire acts upon the water in caverns, cloſed up by very thick ſtrata of ſtones, an apparatus far more effective than Papin's digeſter. The crater was at firſt undoubtedly formed, and is daily ſtrengthened by ſiliceous earth, which quits the menſtruum on its being cooled, falls down, and, being in ſomewhat like a ſoft ſtate, concretes †.

About ſixty yards from the ſhore of the iſland of Iſchia, at a place called St. Angelo, a column of boiling water bubbles on the ſurface of the ſea with great force, and communicates its heat to the

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* Von Troil's Letters on Iceland.

† Bergman's Diſſert. 13.

water of the ſea near it. It boils winter and ſummer, and is of great uſe to the inhabitants in bending their planks for ſhip-building, &c. The fiſhermen alſo frequently employ this curious caldron to boil their fiſh. Near the ſhore of this iſland Sir William Hamilton found, when bathing in the ſea, many ſpots where the ſand was ſo intenſely hot under his feet as to oblige him haſtily to retire.

There is alſo a boiling ſpring near Viterbo, in the Roman ſtate, called the Bullicame. It is a circular pool of about ſixty feet in diameter, and exceedingly deep, the water of which is conſtantly boiling. It is ſituated in a plain ſurrounded by volcanic mountains. A ſtony concretion floats on the ſurface of the pool, which, being carried off by the ſuperfluous water, is depoſited, and is conſtantly forming a labes or tufa, of which the soil all around the pool is compoſed.

Theſe fountains are beſt accounted for by ſuppoſing the pipe or conduit to communicate with a large reſervoir of water, which, being ſubject to the heat of a volcanic fire, the ſteam generated in the reſervoir by the boiling of the water acts forcibly on the water in the ſhaft or pipe, and ejects it by its elaſtic force in the form of a fountain, which will act with more or leſs vigour according to the degree of heat, and according to the reſiſtance which the water encounters in its paſſage.

The moſt ſingular circumſtance is the number of theſe ſprings which are found in almoſt every country; and even in thoſe countries which have long ceaſed to be volcanic. England itſelf has its tepid ſprings, and thoſe of Bath, Buxton, &c. are well known. Cambden mentions a well, near Wigan, in Lancaſhire, which was called the burning well. If a candle was applied to its ſurface, he ſays, a flame was excited like that of ardent ſpirits ſet on fire, and the heat and inflammation thus excited would continue ſometimes for the ſpace of a whole day, and was ſufficient to boil eggs, and even meat. As I recollect, Cambden mentions the well as having loſt its inflammable property in his time; but he notices two others of a ſimilar deſcription, one in the ſame neighbourhood, and another in Shropſhire. I have never myſelf witneſſed a ſimilar phenomenon, nor do I know of any ſuch that exiſts at preſent, at leaſt in Britain.

Should, however, the fact be as it is related by Cambden, the reader, after what has been ſtated in a preceding chapter, will not find it difficult to explain the cauſe. The country where the well is, or was ſituated, abounds in coals. The well is therefore impregnated with naphta, or ſome bituminous vapour; this, upon the application of an ignited body, is capable of inflammation, and can even communicate a conſiderable portion of heat to the water of the well itſelf. There is no proof, however, that the Bath or Buxton waters are impregnated with any bituminous matter, though coals are plentiful in the neighbourhood; and as theſe waters contain a ſmall portion of iron, there is reaſon to ſuppoſe them connected with beds of pyrites, or poſſibly with a latent ſubterraneous fire.

On the whole, we are not ſufficiently acquainted with the internal parts of the earth to account ſatisfactorily for theſe and other phenomena of a ſimilar kind, and whatever is advanced in the way of theory on theſe topics ſhould be advanced with becoming diffidence, and rather with a view of exciting the attention and curioſity of others, than for the purpoſe of eſtabliſhing a ſyſtem unſanctioned by experiment, or building a reputation on the fallible baſis of mere hypotheſis.

CHAP. VIII.

MINERAL WATERS.

Capacity of Water as a Solvent.—Subſtances commonly found in Mineral Waters.—Fixed Air.—Mineral Acids.—Alkaline Salts.—Neutral Salts.—Earthy Subſtances.—Sulphur.—Metals.—Mode of examining and analizing Mineral Waters.—Chemical Teſts.—Analyſis of the moſt celebrated Mineral or Spa Waters.—Aix-la-Chapelle.—Bath.—Briſtol.—Buxton.—Cheltenham.—Epſom.—Harrowgate.—Matlock.—Pyrmont.—Scarborough.—Spa.—Reflections on the Uſe of Mineral Water in general.

THE capacity which water has of holding a variety of ſubſtances in ſolution has been frequently mentioned in the courſe of theſe volumes, and indeed is a fact ſo well known and underſtood, that to inſiſt much upon it would be uſeleſs and even impertinent.

It was alſo intimated, that the water of ſprings receives the name of mineral water from the foreign ſubſtances which are contained in it. Theſe ſubſtances are various, and more than one is commonly found in mineral waters; but in general they may be referred to the following heads:

1. Fixed air, or carbonic acid gas. This ingredient occaſions an appearance of briſkneſs in water, ſimilar to that of fermenting liquors, which is chiefly obſervable when the water is poured from one veſſel into another. It is very volatile, and ſoon eſcapes on the water being expoſed to the air. This

ingredient frequently occaſions giddineſs in perſons who are not accuſtomed to it. An artificial water of this kind may be prepared at any time by impregnating water with fixed air.

2. The vitriolic, nitrous, and muriatic acids. One or other of theſe acids exiſt in almoſt all mineral waters; they are uſually combined with earthy or metallic baſes, but ſometimes, eſpecially the vitriolic, exiſt in a ſeparate ſtate, ſo as to occaſion a ſenſible acidity.

3. An alkaline ſalt is found in many waters in Hungary, Tripoli, and other countries. It is uſually the foſſil alkali which is combined with fixed air in the Seltzer waters, and with the mineral acids in a great variety of others. The vegetable and volatile alkalies rarely or never are ingredients in mineral waters.

4. Neutral ſalts are not uncommon in ſprings. Common ſalt, nitre, and vitriolated magneſia, are the moſt uſual; the latter is very abundant in a ſpring at Epſom, in Surrey, and has therefore obtained the name of Epſom ſalt. Sal amoniac has alſo been found in ſome ſprings in the neighbourhood of volcanoes and burning coal mines.

5. Earthy ſubſtances. Of theſe the calcareous is ſometimes found to abound ſo much, as to be depoſited on ſuch ſubſtances as it comes in contact with, and occaſion petrifaction. In this caſe the ſuſpenſion of the calcareous earth ſeems to depend on the preſence of fixed air, which, making its eſcape when the water iſſues into the open air, ſuffers the calcareous earth to ſeparate. The calca-

reous earth of waters is very commonly united with the vitriolic acid, and exiſts in the form of gypſum, which is only ſoluble in water in the proportion of one part in ſeven or eight hundred. Calcareous nitre and muriated calcareous earth are alſo occaſionally found in ſprings.

6. Sulphur. Many waters ſeem by their offenſive ſmell to contain ſulphur, though very few of them, upon more accurate examination, are found to afford it. The waters generally called ſulphureous or hepatic, are only impregnated with ſulphureous or hepatic gas, which is a ſolution of ſulphur in inflammable air. This is the ſame gas which riſes from liver of ſulphur, and liver of ſulphur itſelf has been detected in a very minute quantity in mineral waters. Sometimes bitumens are met with in mineral waters, and commonly make their appearance on the ſurface.

7. Metals. Of theſe iron is moſt frequently found in water, ſometimes copper, and more rarely zinc. Waters which contain iron are called chalybeates, and are very common.

It was formerly imagined that iron was ſuſpended in mineral waters by means of the vitriolic acid; but M. Monnet has aſcertained, that very few of them contain vitriolic acid, and that the carbonic acid, or fixed air, is almoſt the only medium by which the iron is ſuſpended. The carbonic acid is ſometimes in exceſs, ſo as to render the chalybeate water acidulous, in other inſtances it ſuſpends the iron without being in exceſs. Chalybeates may, in general, be known by the yellow ochry ſediment depoſited in their courſe, and alſo by ſtriking a purple colour with decoction of galls.

In examining any mineral waters, the firſt object of attention is, to have the water as freſh as poſſible, ſince, if it contains any volatile matters, they will ſoon fly off. A great number of trials are therefore to be made on the ſpot. The contents of the neighbouring ſtrata, particularly of any high ground, from which the water ſeems to proceed, are alſo to be regarded, as they often ſerve to account for the properties of mineral waters.

One of the moſt obvious circumſtances to be attended to is the degree of the heat of the water, and for this purpoſe it is neceſſary to be provided with an accurate thermometer. There are many ſprings which have a temperature a little above the medium temperature of the atmoſphere, though this may not be ſo remarkable as to have obtained them the name of hot ſprings. The middle temperature of theſe ſprings is found to be about forty-eight degrees, but on elevated ſituations it is leſs, in proportion to their height above the ſea. It may alſo be proper to compare the temperature of theſe mineral ſprings with that of ſome common ſprings in the neighbourhood. The ſenſible qualities, as the colour, taſte, and ſmell, are to be obſerved. In order to diſcover whether any elaſtic fluid eſcapes from it, and of what nature it is, let ſome of the water be put into a bottle, and a bladder tied about its neck. The air which eſcapes may be ſubmitted to examination. In order to obtain it, it is only neceſſary to tie another ſtring above the bottle, and then to cut between them, ſo as to ſeparate the bladder, which may be plunged in water or mercury, and its contents received in the pneumatic apparatus. In order to ſeparate all the air from water, it muſt be heated nearly to its boiling point, which may eaſily be done by immerſing it in a veſſel of boiling water, while it is contained in the bottle to which the bladder is annexed. The elaſtic fluids, which may be ſeparated from mineral waters, are chiefly two, carbonic acid gas, and ſulphureous gas. It is proper to obſerve the changes which are ſpontaneouſly produced on mineral waters by different degrees of heat. If any matter is depoſited during the evaporation of the mineral water, it muſt be collected for further examination.

With reſpect to the addition of certain foreign ſubſtances called re-agents, to diſcover the contents of mineral waters, it may in general be remarked, that this mode is leſs certain than evaporation; the latter method, however, is not free from objections, as the application of heat to any body not unfrequently deranges the previous ſtate of combination among its component principles. The chemical teſts beſt adapted to the diſcovery of the contents of mineral waters are the following: lime, volatile alkali, fixed alkalies, vitriolic acid, tincture of turnſole, muriated barytes, acid of ſugar, arſenic, Pruſſian alkali, and the nitrous ſolutions of ſilver and mercury. When it it propoſed to diſcover the contents of a mineral water, it is beſt to begin with ſuch teſts as are leaſt capable of altering it, and afterwards, having obſerved their effects, to proceed to complete the analyſis by teſts which have a more extenſive influence. Lime water ſeizes the carbonic acid, and forms a precipitate of chalk; it alſo precipitates ſalts with the baſis of clay and magneſia, as well as the metallic ſalts. If after mixing an equal quantity of lime water with a mineral water, no precipitation takes place in twenty-four hours, it may be concluded, that it contains neither carbonic acid at liberty, nor a combination of that acid with fixed alkali, nor earthy ſalts with the baſis of aluminous earth or magneſia, nor any metallic ſalt. But if a precipitation takes place on the addition of lime water, the next ſtep is to examine the properties of the precipitated matter; if it has the properties of chalk, ſuch as inſipidity, the producing of an efferveſcence with vitriolic acid, and forming with it a compound nearly inſoluble in water, that is gypſum, it muſt be concluded that the water contained carbonic acid, which, uniting with the lime of the lime water, produced chalk. If, on the contrary, the precipitated matter is ſmall in quantity, and ſubſides very ſlowly; if it does not effervesce, and affords with the vitriolic acid a ſtyptic ſalt, it may be concluded that it is alum, and that the mineral water contained clay: If a bitter and very ſoluble ſalt is formed on the addition of the vitriolic acid, it is the Epſom ſalt, and the water contained the earth of magneſia. If the addition of vitriolic acid to the precipitate produces ſal martis, the water held iron in ſolution.

The addition of cauſtic volatile alkali will act like lime water, except that it will not produce a precipitation from the preſence of uncombined carbonic acid in the water; the compound formed by volatile alkali with that acid not being inſoluble, like the chalk formed by the union of carbonic acid with lime. But beſides the aluminous, the magneſian, and the metallic ſalts, the cauſtic volatile alkali will decompoſe thoſe which have lime for their baſis, and thus we advance one ſtep further in the analyſis of the water. The Pruſſian alkali precipitates the combinations of carbonic and vitriolic acid with chalk. The nitrous ſolutions of ſilver and mercury decompoſe all the muriatic and vitriolic ſalts, which may be various both in quantity and in kind. In theſe caſes the muriatic or vitriolic acid contained in the mineral water, ſeizes the ſilver or the mercury, and forming with it an inſoluble compound, falls to the bottom in a thick cloud, while the nitrous acid unites with the baſis which is deſerted by one or both of the other acids. It is not neceſſary in this place to enter into a minute detail of the methods of diſtinguiſhing the difference of the precipitates, according as the muriatic or vitriolic acid was concerned in their production, but I ſhall refer the reader for information on this point to what was ſtated when treating of the combinations of ſilver and mercury with the different mineral acids.

By tincture of turnſole the predominance either of an alkali or an acid is diſcovered: as vegetable blues are turned red by acids, and green by alkalies. Acid of ſugar is a very ſenſible teſt of lime, when combined with the ſparry or acetous acids. A ſolution of arſenic in the marine acid will precipitate ſulphur from water, in which it is held diſſolved by means of carbonic acid. It may be added, that white arſenic becomes yellow if immerſed in water containing hepatic gas; and a piece of poliſhed iron will receive a copper-colour from water in which copper is diſſolved. If a mineral water is found to contain a fixed alkali, it may be determined whether it is the vegetable or mineral alkali by means of vinegar. With vegetable alkali vinegar yields a deliqueſcent ſalt; with the mineral, foliated cryſtals.

It may be proper briefly to notice the compoſition and obvious properties of ſome of the moſt celebrated mineral waters, and the diſorders in which they are ſuppoſed to have moſt efficacy.

' AIX-LA-CHAPELLE.—This place has long been famous for its hot ſulphureous waters and baths. They ariſe from ſeveral ſources, which ſupply eight baths conſtructed in different parts of the town. Theſe waters near the ſources are clear and pellucid, and have a ſtrong ſulphureous ſmell reſembling the waſhings of a foul gun; but they loſe this ſmell by expoſure to air. Their taſte is ſaline, bitter, and urinous. They do not contain iron. They are alſo neutral near the fountain, but afterwards are manifeſtly, and pretty ſtrongly alkaline, inſomuch that cloaths may be waſhed with them without ſoap. The gallon contains about two ſcruples of ſea ſalt, the ſame quantity of chalk, and a dram and half of natron. They are at firſt nauſeous and harſh, but by habit become familiar and agreeable. At firſt drinking alſo they generally affect the head. Their general operation is cathartic and diuretic, without griping or diminution of ſtrength; and they alſo promote perſpiration. The quantity to be drunk as an alterative, is to be varied according to the conſtitution, and other circumſtances of the patient. In general, it is beſt to begin with a quarter, or half a pint in the morning, and increaſe the doſe afterwards to pints, as may be found convenient. The water is beſt drunk at the fountain. When it is required to purge, it ſhould be drunk in large and often repeated draughts *.'

The heat of the different baths of the Aix-la-Chapelle waters varies from one hundred and ſix of Farenheit's thermometer to one hundred and thirty. In bathing it is proper to begin with the moſt temperate.

' Bath has long been famous for its warm chalybeate waters. There are ſeveral ſprings, but their waters are all of the ſame nature. There are ſix baths; but the principal are the *King*'s bath, the *Queen*'s bath, and the *Croſs* bath. The others are only appendages to theſe. The two former raiſe the thermometer to 116°, the latter to 112°. The water when viewed in the baths has a greeniſh, or ſea colour: but in a phial it appears quite tranſparent and colourleſs, and it ſparkles in the glaſs. It has a very ſlight ſaline, bitteriſh, and chalybeate taſte, which is not diſagreeable, and ſometimes ſomewhat of a ſulphureous ſmell; but this latter is not uſually perceptible, except when the baths are filling. The gallon of Bath water contains twenty-three grains of chalk, the ſame quantity of muriat of magneſia, thirty-eight of ſea ſalt, and 8. 1 of aerated iron. As it riſes from the pump, it contains fixed air, or other volatile acid, in a ſufficient quantity to curdle milk and act upon iron. The Bath water operates powerfully as a diuretic, and promotes perſpiration. If drunk quickly, in large draughts, it ſometimes purges; but if taken ſlowly and in ſmall quantity, it rather has the contrary effect. An heavineſs of the head, and inclination to ſleep, are often felt on firſt drinking it*.'

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* Elliot on Min. Waters, p. 119, &c.

This water when taken inwardly is ſaid to give a ſtimulus and vigour to the whole conſtitution, it therefore proves uſeful in old rheumatic complaints, and in caſes of gout connected with much debility. During the uſe of the Bath water, and ſome time previous to it, the patient ſhould live on a light diet, eaſy of digeſtion. The courſe ſhould be continued for a month or ſix weeks. In local complaints, as in ſtiff joints and chronic pains, the application of the water by pumping is more efficacious than bathing the whole body.

Bristol, 'The ſprings are known by the name of the *Hot Wells*. The water at its origin is warm, clear, pellucid and ſparkling; and if let ſtand in a glaſs, covers its inſide with ſmall air-bubbles. It has no ſmell, and is ſoft and agreeable to the taſte. It raiſes the thermometer from about ſeventy to eighty degrees. It contains 12¾ grains of chalk, 5¾ of muriat of magneſia, and 6½ of ſea ſalt in the gallon*.'

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* Elliot on Min. Waters, p. 134, &c.

The Briſtol waters are particularly recommended in pulmonary complaints; the fame, however, of Briſtol has probably been more owing to the mildneſs of the air in that part of England, than to the virtues of its waters.

Buxton.—' This is a hot water, reſembling that of *Briſtol.* It raiſes the thermometer to 81° or 82°. It has a ſweet and pleaſant taſte. It contains a little calcareous earth, together with a ſmall quantity of ſea ſalt, and an inconſiderable portion of a cathartic ſalt. Iron has been diſcovered in it, but in ſo extremely ſmall a quantity as not to deſerve notice: and even that perhaps owing to accident. This water taken inwardly is eſteemed good in the diabetes; in bloody urine; in the bilious cholic; in loſs of appetite, and coldneſs of the ſtomach; in inward bleedings; in atrophy; in contraction of the veſſels and limbs, eſpecially from age; in cramps and convulſions; in the dry aſthma without a fever; and alſo in barrenneſs. Inwardly and outwardly it is ſaid to be good in rheumatic and ſcorbutic complaints; in the gout; in inflammation of the liver and kidnies, and in conſumptions of the lungs; alſo in old ſtrains; in hard callous tumours; in withered and contracted limbs; in the itch, ſcabs, nodes, chalky ſwellings, ring-worms, and other ſimilar complaints. Beſides the hot water, there is alſo a cold *chalybeate* water, with a rough irony taſte. It reſembles the *Cawthorp* water*.'

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* Elliot on Min. Waters, p. 145, &c.

'CHELTENHAM, *in Glouceſterſhire*, is one of the beſt and moſt noted cathartic chalybeate waters in England, though it is not ſo much frequented as formerly. The gallon contains eight drams of a cathartic ſalt, partly vitriolated natron, partly vitriolated magneſia; twenty-five grains of magneſia, part of which is united with marine, part with aerial acid; and nearly five grains of iron combined with aerial acid. It alſo yielded thirty-two ounce meaſures of air, twenty-four of which were fixed air, the reſt azotic with a portion of hepatic air. The doſe is from one pint to three or four. It operates with great eaſe, and is never attended with gripings, teneſmus, &c. It is beſt taken a little warm. It alſo creates an appetite; is excellent in ſcorbutic complaints, and has been uſed with ſucceſs in the gravel. As the ſpring has been calculated to yield only thirty-five pints of water an hour, without frugal management there would not be enough to ſupply the demands of the drinkers. The Walton water has lately been recommended as a ſubſtitute to obviate this inconvenience.'

EPSOM, *in Surry*.—The water has a ſlight ſaline taſte, is clear, and without ſmell. But if it is kept in covered veſſels for ſome weeks in the ſummer it will ſtink, and acquire a nauſeous and ſaltiſh bitter taſte. This was the firſt water from which the ſalt thence called *Epſom ſalt* was obtained. But the ſalt uſually ſold by that name is different from that yielded by the Epſom water, though perhaps not inferior in virtue. It is made from the bittern left after the cryſtallization of common ſalt from ſea water. The Epſom water is cathartic; for which purpoſe it muſt be drunk to the quantity of two or three pints. It is alſo diuretic.

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* Elliot on Min. Waters, p. 151, &c.

Harrowgate.—' There are four ſprings at this place, but the waters of all of them are nearly alike, except in the quantity of the ſaline matter they contain. Of the three old ſprings, the higheſt gave three ounces of ſolid matter; the loweſt, an ounce and an half; and the middle one, only half an ounce. Of the latter one hundred and forty grains were earth. The water as it ſprings up is clear and ſparkling, and throws up a quantity of air-bubbles. It has a ſtrong ſmell of ſulphur, and is ſuppoſed to be the ſtrongeſt ſulphureous water in England. It has a ſalt taſte, as it contains a conſiderable quantity of ſea ſalt, together with a little marine ſalt of magneſia, and calcareous earth *.'

Harrowgate water is cathartic when taken in doſes of ſeveral pints. When uſed externally as a fomentation, it is ſaid to be uſeful in ſome diſorders of the ſkin; and by ſome phyſicians it is conſidered as efficaceous in deſtroying worms.

Matlock.—' At this place (which is perfectly romantic) are ſeveral ſprings of warm water, which appear to be of the nature of the *Briſtol* water, except that it is very ſlightly impregnated with iron. Its heat is about 69°, and its virtues are ſimilar to thoſe of the *Briſtol* and *Buxton* waters. The baths are recommended in rheumatic complaints, in cutaneous diſorders, and in other caſes where warm bathing is ſerviceable. There are great numbers of petrifactions in the courſe of this water *.'

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* Elliot, p. 177 and 184.

Pyrmont, *in Weſtphalia.*—' This is a very briſk chalybeate, abounding in fixed air; and when taken up from the fountain, ſparkles like the briſkeſt Champaign wine. It has a fine, pleaſant, vinous taſte, and a ſomewhat ſulphureous ſmell. It is perfectly clear, and bears carriage better than the *Spa* water. A gallon of it contains 46 grains of chalk, 15.6 of magneſia, 30 of vitriolated magneſia, 10 of ſea ſalt, and 2.6 of aerated iron †. Perſons who drink it at the well, are affected with a kind of giddineſs or intoxication; owing, it may be ſuppoſed, to the quantity of fixed air with which the water abounds. The common operation of this water is diuretic; but it is alſo gently ſudorific; and if taken in large quantity proves cathartic. When, however, it is required to have this latter effect, it is uſeful to mix ſome ſalts with the firſt glaſſes. It is drunk by glaſsfuls in the morning, to the quantity of from one to five or ſix pints, according to circumſtances, walking about between each glaſs ‡.'

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* Elliot, p. 210.

† Dr. Marcard, in his *Deſcription of Pyrmont,* on the authority of M. Weſtrumb of Hammeln, eſtimates the iron at ſomewhat more than eight grains to the gallon.

‡ Elliot, p. 226.

Pyrmont waters are recommended in debilitated and relaxed conſtitutions, attended with indigeſtion, low ſpirits, and want of appetite.

SCARBOROUGH, *in Yorkſhire.*—'The waters of this place are chalybeate and cathartic; and they are more frequented and uſed than any other water of this claſs in England. There are two wells; the one more cathartic, the other a ſtronger chalybeate. Hence the latter (which is neareſt the town) has been called the *chalybeate* ſpring, the other the purging; though they are both impregnated with the ſame principles, but in different proportions. The purging is the moſt famed, and is that which is uſually called the *Scarborough* water. This contains fifty-two grains of calcareous earth, two of ochre, and two hundred and ſixty-ſix of vitriolated magneſia, in the gallon: the chalybeate, ſeventy grains of calcareous earth, one hundred and thirty-nine of vitriolated magneſia, and eleven of ſea ſalt. When theſe waters are poured out of one glaſs into another, they throw up a number of air-bubbles; and if ſhaken for a while in a cloſe ſtopt phial, and the phial is ſuddenly opened before the commotion ceaſes, they diſplode an elaſtic vapour with an audible noiſe, which ſhows that they abound in fixed air. At the fountain they both have a briſk, pungent, chalybeate taſte; but the cathartic water taſtes bitteriſh, which is not uſually the caſe with the *chalybeate*. They loſe their chalybeate virtues by expoſure, and alſo by keeping; but the cathartic water ſooneſt. They both putrify by keeping; but in time recover their ſweetneſs*.'

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* Elliot, p. 234.

The properties of the cathartic and of the chalybeate ſpring are, as might naturally be ſuppoſed, very different. The former is uſeful in caſes of habitual coſtiveneſs; the latter in diſorders of relaxation and debility.

Spa, *in the biſhopric of Liege.*—' In and about this town there are ſeveral ſprings, which afford excellent chalybeate waters: and in Great Britain they are the moſt in uſe of any foreign mineral waters.

' The principal ſprings are, 1. The *Pohoun*, or *Pouhon*, ſituated in the middle of the village;—2. *Sauviniere*, about a mile and an half eaſt from it;—3. *Groiſbeeck*, near to the Sauviniere;—4. *Tonnelet*, a little to the left of the road to the Sauviniere;—5. *Watroz*, near to the Tonnelet;—6. *Geronſtere*, two miles ſouth of the Spa;—7. *Sarts*, or *Niverſet*, in the diſtrict of Sarts;—8. *Chevron*, or *Bru*, in the principality of Stavelot;—9. *Couve*,—10. *Beverſee*,—11. *Sige*,—12. *Geromont*, all near Malmdy.

' The *Pouhon* is a ſlow deep ſpring, and is more or leſs ſtrong or gaſeous according to the ſtate of the atmoſphere. The gallon contains ten grains of chalk, thirty of magneſia, ten of natron, and five of aerated iron. It yields of fixed air one hundred and thirty-two ounce meaſures. It contains more iron than any of the other ſprings, and does not ſo ſoon loſe its gas. It is in its moſt perfect and natural ſtate in cold, dry weather. It then appears colourleſs, tranſparent, and without ſmell, and has a ſubacid chalybeate taſte, with an agreeable ſmartneſs: at ſuch times, if it is taken out of the well in a glaſs, it does not ſparkle; but after ſtanding a while, covers the glaſs on the inſide with ſmall air-bubbles; but if it is ſhaken, or poured out of one glaſs into another, it then ſparkles, and diſcharges a great number of air-bubbles at the ſurface. In warm, moiſt weather, it loſes its tranſparency, appears turbid or wheyiſh, contains leſs fixed air, and is partly decompoſed. A murmuring noiſe alſo is ſometimes heard in the well. It is colder than the heat of the atmoſphere by many degrees. It is ſuppoſed to contain the greateſt quantity of fixed air of almoſt any acidulous water; and conſequently has a remarkable ſprightlineſs and vinoſity, and boils by mere warmth. This, however, ſoon flies off, if the water is left expoſed; though in well corked bottles it is in a great meaſure preſerved. It is capable of diſſolving more iron than it naturally contains, and thus becoming a ſtronger chalybeate. This is owing to the great quantity of fixed air which it contains. For the ſame reaſon an ebullition is raiſed in this water on the addition of acids, as they diſengage its fixed air. It mixes ſmoothly with milk, whether it is cold or of a boiling heat.

' Of the *Sauviniere* water, a gallon yields 6.5 grains of chalk, 4.5 of magneſia, two of natron, 3.5 of kali, 2.2 of aerated iron, and 108 ounce meaſures of fixed air. At the well it has ſomewhat a ſmell of ſulphur.

' *Groiſbeeck.* The water is of the ſame nature as the Sauviniere, but contains a ſomewhat larger proportion of the ſeveral ingredients. It has a vitriolic taſte, and ſomewhat of a ſulphureous ſmell.

‘ *Tonnelet.* This is one of the moſt ſprightly waters in the world. It is much colder than either of the other Spa waters; has no ſmell; is bright, tranſparent, and colourleſs; and from the rapidity of its motion does not foul its baſon. It has a ſmart, ſubacid, ſprightly taſte, not unlike the briſkeſt Champaign wine. From a variety of experiments it appears, that this water is more ſtrongly charged than any of the others with fixed air, on which the *energy* of all waters of this kind principally depends, but it parts with it more readily. It contains more iron than any of the ſprings, except the Pouhon.

‘ *Watroz.* Its ſituation is loweſt of any of the ſprings about Spa, and it is more apt to be foul: but when the well is cleaned out, and the water pure, it is found to be of the ſame nature as that of Pouhon. It is not cathartic, as ſome have aſſerted.

‘ *Geronſtere.* This water has much leſs fixed air than the Pouhon. It has a ſulphureous ſmell at the fountain, which it loſes by being carried to a diſtance. This ſmell is ſtrongeſt in warm moiſt weather. The air, or vapour, of this water affects the heads of ſome who drink it, occaſioning a giddineſs, or kind of intoxication, which goes off in a quarter or half an hour. The Pyrmont, and ſeveral other briſk chalybeate waters, are found to have the ſame effect. It is colder than any of the ſprings, the Tonnelet excepted.

‘ *Sarts,* or *Niverſet.* It reſembles the Tonnelet water, but is rather leſs briſk and gaſeous. It is however more acid and ſtyptic.

‘ *Bru*, or *Chevron*. The phyſicians at Liege have artfully decried this water, becauſe it is not in the principality of Liege. But by every trial it appears not much inferior to any of the Spa waters. In the quantity of fixed air and of iron it contains, it approaches the Pouhon.

‘ *Couve* and *Beverſee*. The Couve nearly reſembles the Tonnelet water; or rather, may be placed in a medium between that and the Watroz. It hardly equals the tranſparency, ſmartneſs, and generous vinous taſte of the firſt, but it greatly ſurpaſſes the latter. The Beverſee agrees with this, only that it does not retain its ſmartneſs ſo well by keeping.

‘ *La Sige*. It has ſome of the general properties of the Spa waters, but in other reſpects it is different. It is moderately ſubacid, ſmart, and grateful, but has no ſenſible chalybeate taſte. It ſparkles like Champaign when poured from one glaſs to another. Upon ſtanding it loſes its fixed air, and throws up a thick mother-of-pearl coloured pellicle. It is much more loaded with earthy matters, and leſs impregnated with iron and fixed air, than the other Spa waters.

‘ *Geromont*. As a chalybeate and acidulous water it ſeems to be nearly of the ſame ſtrength with La Sige; but it contains a greater quantity of natron, together with a mixture of ſea ſalt. The earthy matters, however, are leſs.’ It appears, that theſe waters are compounded of nearly the ſame principles, though in different proportions. All of them abound with *fixed air*. They contain more or leſs iron, natron, and calcareous and ſelenitical earths; together with a ſmall portion of ſea ſalt. Theſe are all kept ſuſpended, and in a neutral ſtate, by means of the aerial acid, or fixed air. From a review of the contents of theſe waters. it cannot be imagined that their virtues principally depend on the ſmall quantity of *ſolid* matters which they contain. They muſt therefore depend moſtly on their *fixed air*. And they are probably rendered more active and penetrating both in the firſt paſſages, and alſo when they enter the circulation, by means of that ſmall portion of iron, earth, ſalt, &c. with which they are impregnated *.

After all that has been alleged in favour of mineral waters, it muſt be confeſſed that their medical virtues are at beſt rather dubious. With reſpect to the metallic ſalts which they may contain, the quantity is too minute to be very efficacious in obſtinate complaints; and the warm baths have probably no other effect than a quantity of common water heated to the ſame temperature would have, if applied by means of an artificial bath at home. Where good effects have been wrought upon a patient's reſorting to a mineral water, phyſicians have overlooked the excellent conſequences which in the common courſe of things might be expected from the exerciſe of the journey, the change of air, and change of ſcene, from cheerful company, and, though laſt, not leaſt, perhaps, from the imagination of the patient.

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* See Elliot, p. 249, &c.

APPENDIX.

TABLE OF SPECIFIC GRAVITIES.

DISTILLED water	1000
Calcareous Earth	2723
Magneſian earth	2155
Barytic earth	3973
Argillaceous earth	1669
Siliceous earth	2650
Bottle glaſs	2732
White glaſs	2892
Flint glaſs	3329
Seves porcelain	2145
China ditto	2384
Lime ſtones, from	1386
——— to	2390
Common ſlate	2672
Muſcovy talk	2792
Calcareous ſpar	2715
Fluor ſpar	3180
White marble	2716
Diamond	3445
Ruby	4213
Topaz	3460
Emerald	3600
Hyacinth	3764
Garnet	3978
Tourmaline	3050
Opal	2764
Cat's eye	2240
Onyx	2600
Carnelion	2704
Common flint	2700
Jaſper	2778
Quartz	2654
Agate	2590
Gold	19640
Platina	22000
Mercury	13568
Lead	11352
Silver	10474
Copper	8878
Iron	7788
Tin	7299
Biſmuth	9823
Nickel	8660
Arſenic	5763
Zinc	7191
Antimony	6702
Manganeſe	6850
Cobalt	7811
Tungſtein	6066
Molybdena	4738
Vitriolic acid	2472
Nitrous acid	1682
Muriatic acid	1085
Fluor acid	1500
Oil of olives	915
Linſeed oil	940
Burgundy wine	991
Bourdeaux ditto	993
Malmſey madeira	1038
Cyder	1018
Woman's milk	1020
Mare's milk	1034
Cow's milk	1032
Goat's milk	1034
Ewe's milk	1040
Elaſtic gum	933
Naptha	708
Camphor	989
Spermaceti	943
Tallow	942
Vitriolic æther	739
Nitrous æther	909
Muriatic æther	730
Acetous æther	866
Pureſt ſpirit of wine	820

TABLE of the weights of the different gaſſes at 29. 84. Engliſh inches, barometrical preſſure, and at 54. 5° of temperature, according to Fahrenheit's thermometer, expreſſed in Engliſh meaſure, and Engliſh tróy weight. From Lavoiſier's Chemiſtry.—The weight of the five firſt were aſcertained by M. Lavoiſier himſelf; the laſt three were inſerted by M. Lavoiſier on the authority of Mr. Kirwan.

Names of gaſſes.	Weight of a cubical inch.	Weight of a cubical foot.		
		oz.	*dr.*	*grs.*
Atmoſpheric air -	. 32112	1	1	15
Azotic gas - - -	. 30064	1	0	39 . 5
Oxygen gas - -	. 34211	1	1	51
Hydrogen gas - -	. 02394	0	0	41 . 26
Carbonic acid gas -	. 44108	1	4	41
Nitrous gas - - -	. 37000	1	2	39
Ammoniacal gas -	. 18515	0	5	19 . 73
Sulphureous acid gas	. 71580	2	4	38

END OF THE SECOND VOLUME.